

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE
FOREST PRODUCTS
RESEARCH BOARD
FOR THE YEAR 1938

THIS REPORT WILL
BE PUBLISHED ON
1 JAN 1940

PRICE 1s. 6d. NET

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE
FOREST PRODUCTS
RESEARCH BOARD

With the Report of the
Director of Forest Products Research
FOR THE YEAR 1938

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1938

*To the Lords of the Committee of the Privy Council for Scientific and
Industrial Research*

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to present our Report on Forest Products Research for the year 1938.

In the early part of the year we considered a Memorandum submitted by the Director of Forest Products Research on the expediency of his attending a Conference of the Permanent Committee of the Timber Testing Committee of the International Union of Forest Research Organizations held in Finland in August. We considered that his attendance was highly desirable and therefore decided to recommend that the necessary facilities for his visit be granted. His report on his tour has been circulated to the members of the Board.

We have had under consideration detailed proposals for the provision of equipment for research on composite wood, with a revised estimate of cost, and we made recommendations, which have been approved, for obtaining this equipment.

We are impressed with the need for systematic research on the properties of this class of materials in order to build a foundation of technical knowledge such as has been accumulated in the case of "solid" wood by many years of work at various universities and laboratories in the past. In view of the importance which the processes of manufacture and the inter-relations of the materials used have on the properties of the final products the need for systematic research is evident. The fundamental difference between these final products and solid wood leads us to believe that fresh methods of test and investigation may have to be developed and we are informed that research workers in foreign countries are tending to the same opinion. The new methods of investigation need to be based on research into the properties and behaviour of the materials in the new forms in which they find themselves in the process of manufacture. Little or nothing is known on this point save that the conditions are probably very different from those of the uncombined materials.

The rapidly increasing number of inquiries about these products which are reaching the Laboratory, even though the possession of any real technical knowledge of them has been disclaimed, impresses us with the importance attached to such knowledge by industry. The industries interested in these products cover every field in which "solid" wood has been used hitherto and several in which the use of wood has practically been abandoned.

The Timber Development Association having been unable, for lack of adequate funds, to take any further action to expedite, in co-operation with the Board, the test work leading to the establishment of an adequate grading schedule for structural timber, we agreed that no work, additional to that already approved and included in the programme of work on the testing of timbers in structural sizes, should be undertaken.

We noted with satisfaction the progress of the investigations on the carbonization of wood in portable kilns, the first results of which are to be published shortly.

J. C. IRVINE,
Chairman.

June, 1939.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1938

I. GENERAL

Introduction

The progress of research in the various sections of the Forest Products Research Laboratory has been generally satisfactory during the year under review. Particulars of certain investigations which have been completed, or in which results of sufficient importance to justify their publication have been achieved, may be found in Appendix III to this Report. Details of progress made in such branches of the work as are still in progress are epitomized, and brief reference is made to other of the Laboratory's activities, such as its educational and advisory work.

An appreciable advance has been possible in the elucidation of problems connected with the moisture relations of wood in their bearing on its behaviour under varying conditions of relative humidity. The results already obtained have thrown light from a new angle on difficulties which have frequently arisen in the process of seasoning and in the application of timber to some of the more exacting uses.

Further progress, of more direct importance to industry, has been achieved in the study of problems connected with woodworking processes and the principles involved in the economical and efficient operation of machine tools. In this connexion it is satisfactory to note that there is a growing appreciation in timber-using industries of the fact that the variable properties in different woods must entail modifications to what has been considered standard practice on the grounds both of efficiency and economy. Such modifications permit of the use of timbers which without them would be considered too refractory or too costly to work.

Plans for the extension of the research programme to cover more detailed investigation of problems arising in the manufacture and use of veneers, plywood, laminated wood products and other forms of composite wood have already been made, and the necessary equipment for such further work has been acquired. The numerous inquiries concerning such materials, which have recently been received, afford ample testimony of the need for such research and of its rapidly increasing importance to industry.

Improvements in research methods and in the technique of testing have attracted the attention of scientific workers in the same field in other countries, as an outcome of which several have sought facilities for the study of those methods during the year. They have included research workers from both Empire and foreign countries, and the decision to hold the meetings of the Sub-committee on Timber Research of the International Union of Forest Research

Organizations at the Laboratory when the Annual Conference is held in April, 1939, is worthy of mention.

The total number of persons employed at the Laboratory on 31st December was 141.

Educational Activities

The fourth of the series of summer courses in general technology of wood was held in the week beginning 29th August. Forty-six students, drawn from practically all the industrial centres of the country, attended, and for lack of accommodation approximately half that number of applications had to be refused. The course, which had been slightly modified and extended, was highly appreciated and was without doubt the most successful. Letters which appeared in the trade press and were received at the Laboratory testified to the value of the instruction given, and inquiries concerning a similar course in 1939 began to arrive at the Laboratory in September. The number of requests for special tuition in particular subjects, especially seasoning, has increased to such an extent that it has been found advisable, in order to minimize the interference with the research work of the section, to arrange a course in seasoning for twenty students in the early part of 1939.

A number of officers from the forest services of the different parts of the Empire have received instruction at the Laboratory during the year, and in addition several firms have sent representatives for periods of from one to six weeks. Some twenty lectures have been given by officers of the Laboratory in various parts of England and five have been delivered in Scotland.

Exhibitions

A Timber Research and Utilization Exhibition, for which the Laboratory was largely responsible, was opened at the Science Museum, South Kensington, early in December, 1937, and was continued through January, 1938. During the fifty-two days on which it was open to the public approximately 56,000 visitors, including a party of instructors and students from the Army Vocational Training Centre at Aldershot, attended. Later in the year a similar exhibition was prepared and staged at the College of Technology, Manchester. This was well attended by students and members of the building, woodworking and timber trades, and a series of lectures was arranged in conjunction with the exhibition.

An exhibit was prepared for incorporation in the Department's exhibition at the Building Trades Exhibition at Olympia in September. The small semi-permanent exhibit at the Building Centre, New Bond Street, London, was renewed during the year.

Exhibits were prepared and loaned to the Forestry Commission and the Timber Development Association for their stands at the Glasgow Empire Exhibition, and further small exhibits were loaned to the Royal English Forestry Society for use at two agricultural shows.

Many valuable contacts are made at exhibitions of this type, and probably a far greater number of subsequent inquiries are traceable to such contacts than is immediately apparent.

Publications

Evidence of a general desire for technical information on matters associated with the economic utilization of wood in industry is to be found in the increasing interest which is being shown in certain of the Laboratory's publications. The first edition of the Handbook of Home-grown Timbers, which was put on sale in January, 1937, has been exhausted and a revised, enlarged edition has been prepared. A companion volume on Empire Timbers, which gives detailed information of the properties of nearly one hundred species, has also been prepared for publication. Certain of the Forest Products Research Records have been in such demand that one was reprinted within three months, and several others within twelve months of the dates of publication.*

Collection of Wood Specimens

The Laboratory reference collection of wood specimens has been enlarged by some important additions from different parts of the Empire received through the forest departments of Sierra Leone, Trinidad, Tanganyika Territory, and the Union of South Africa, with smaller collections from New Zealand and New Britain, the last-named through the courtesy of the Australian Division of Forest Products. Other notable acquisitions include specimens of Brazilian and Chilean timbers and a collection of Florida timbers from a private collector in the U.S.A. Nearly 300 new species have been added to the collection, bringing the total number of different timbers to 4,357. Approximately 800 duplicate wood specimens and microscope slides have been distributed during the year.

Collection of Fungi

The maintenance of the collection of standard cultures of wood-destroying fungi remains an important part of the work of the mycological section. Numerous requests for sub-cultures of fungi for test and research purposes have been received. A number of new species has been added, and fresh isolations of any species which did not appear to be growing sufficiently vigorously have been prepared. Cultures of some of the principal fungi associated with heart rot in various trees in India have been received from the Forest Research Institute at Dehra Dun, and certain cultures of fungi collected on timber in the Rand Mines have been sent for identification from the Timber Laboratory of the Transvaal Chamber of Mines. To assist in the identification of fungi isolated from samples of Empire timbers sent in for diagnosis, it is desirable that cultures of more of the common wood-rotting forms from the tropics should

* For full particulars of publications see Appendix III, p. 75.

be available for comparative purposes, and it is hoped that these will be gradually collected through the kind co-operation of mycologists in the dominions and colonies.

Further specimens have been added to the collection of sporophores of wood fungi and of typical rots. During visits to Scotland the mycologists were able to do some field collecting and obtained specimens and photographs of a number of fungi which occur only in the Highlands.

A small mycological museum is being built up, one room of the experimental house having been redecorated and fitted with additional exhibition cases for the purpose.

II. PROGRAMME OF RESEARCH

Wood Structure and the Properties of Timber

In comparison with other raw materials timber is more variable and apt to be less dependable unless due regard is paid to those features which influence its technical properties. It is obvious that timber can be used to better advantage if the reasons for its variation are understood and, with this end in view, a long series of investigations has been made into the relations between the growth, structure and properties of wood.

The systematic investigation of anatomical structure in relation to the physical and mechanical properties of timber was initiated in this Laboratory in 1928. This work is based on the structural examination of specimens the physical properties of which have been determined under standard conditions. Some of the results of these investigations have been published at intervals during the last ten years, and the principal findings have now been summarized in a Special Report⁽¹⁾, which also reviews the present position of the knowledge in this field, and indicates the lines on which future research should be planned.

Among the observations not previously recorded is a comparison of the factors influencing strength in resistance to compression and toughness. It is apparent that these properties depend largely on quite distinct structural characters of the wood, and that some factors making for an increase in compressive strength cause a reduction in toughness. In general, resistance to longitudinal compression is dependent on the properties of the secondary walls of the wood fibres, whereas toughness depends rather on the proportions and arrangement of the conducting and storage tissues, and on the properties of the middle lamellae and primary walls of the fibres.

During the past year investigations of tension wood have been continued on material from trees of various species received at the Laboratory for test. Examination of specimens from branches and

a leaning stem of English ash indicates that the hitherto unexplained variations in lignification in this timber are due to the development of tension wood. In ash this abnormal tissue is not as a rule characterized by the gelatinous fibres which distinguish tension wood in most hardwoods. Comparative tests on a number of different species have shown that the abnormal strength properties of tension wood are less pronounced in wood in the seasoned than in the green condition.

It has become increasingly apparent in recent years that in order to elucidate the properties of timber the ultramicroscopic structure of the cell wall must be taken into consideration. A number of important papers on this subject have recently emanated from botanical laboratories on the Continent. It is part of the work of the Laboratory to keep in touch with the work of investigators in other countries, and a review of current trends in the relevant literature has been published during the year⁽²⁾.

(1) CLARKE, S. H. Recent Work on the Growth, Structure and Properties of Wood. *Spec. Rep. For. Prod. Res., Lond.*, 1939, No. 5.

(2) CLARKE, S. H. The Fine Structure of the Plant Cell Wall. *Nature*, 1938, **142**, 899-904.

Studies of Commercial Timbers

There is a limited number of timbers which by virtue of their peculiar properties are mainly used for certain special purposes. The relatively high prices paid for these woods make the market an attractive one to producers, and from time to time inquiries are addressed to the Laboratory regarding the characteristics which render a wood specially suitable for these particular purposes and the possibility of finding substitutes. An outstanding example of this type of inquiry relates to the commercial boxwoods, with which may be included two other woods used in the manufacture of shuttles for the textile industry, namely American persimmon and cornel. Manufacturers and users are generally familiar with the three or four principal species of boxwood but are not always aware of the variety of timbers which are used for the same class of work. On the other hand forest departments and other producers of timber are not in possession of the knowledge which would enable them to put forward other species for test as substitutes. During the year a study has been made of the essential structural and other characteristics of these woods⁽¹⁾. This has the dual object of bringing together the information on the relative merits of woods in this class and of indicating the botanical families and genera which may be expected to furnish timbers with similar properties.

(1) RENDLE, B. J. Substitutes for Persimmon and Cornel for the Manufacture of Shuttles. *F.P.R. Proj. 9, Prog. Rep. 7* (1938).

RENDLE, B. J. Commercial Boxwoods and Similar Timbers. *F.P.R. Proj. 9, Prog. Rep. 8* (1938).

The Identification of Timbers

The construction of the key for the identification of hardwoods, using a patented system of perforated cards, has been revised in the light of experience and of suggestions made by other workers. A description of the key in its revised form has been published⁽¹⁾ and the work of examining about four hundred commercial timbers and incorporating their descriptive characters in the key has been completed during the year. The practical value of the system in reducing the time spent in identification is a matter of importance in view of the increasing number of specimens submitted to the Laboratory every year for examination and report. Consideration has been given to preparing for field use a similar key based on features visible with a hand lens, and a list of characters suitable for use in such a key is being worked out in collaboration with the Imperial Forestry Institute.

The identification of softwoods has also received special attention during the year. This group of timbers calls for a somewhat different treatment as, although the number of commercial species is relatively small, they show a remarkable uniformity in anatomical structure, and the number of reliable diagnostic features is very limited. This circumstance has led many investigators to attribute undue importance to minor features of little actual value in differentiating closely related species. For several years past the problem has been the subject of systematic investigation in the Laboratory. A fairly representative collection of authentic specimens has been accumulated, and a critical examination has been made of all features of possible diagnostic value. As a result of this work a multiple-entry card key (Fig. 1) has now been evolved and a comprehensive report on the work is in preparation.

(1) CLARKE, S. H. A Multiple-entry Perforated-card Key, with Special Reference to the Identification of Hardwoods. *New Phytol.*, 1938, **37**, 369-374.

CLARKE, S. H. The Use of Perforated Cards in Multiple-entry Identification Keys and in the Study of the Inter-relation of Variable Properties. *Chronica botanica*, 1938, **4**, 517-518.

Statistical Methods

(a) Uniformity Trials

In planning experiments to compare the effects of treatments on various properties, recourse is often made to the matching of two or more pieces in order to discount the effect of the considerable variation in wood. It is an advantage, when planning experiments, to know beforehand what degree of variation to expect between test pieces matched in a particular way. This knowledge may, for instance, affect the choice of the number of pieces tested. Data of this kind are being collected for the various properties commonly measured. Where data are scarce it is sometimes found advantageous

GEOGRAPHICAL REGIONS										PAT. NOS. 225063, 257992									
C ☐ B ☐ Y ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐										L ☐ M ☐ N ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐									
EUROPE 43 ☐										INDIA ETC. 44 ☐									
MALAYA 45 ☐										CHINA, JAPAN 46 ☐									
AUSTRALIA 47 ☐										NEW ZEALAND 48 ☐									
N. AMERICA 49 ☐										CENT. " 50 ☐									
TEM. S. " 51 ☐										TROP. AFRICA 52 ☐									
S. AFRICA 53 ☐										54 ☐									
G. RINGS INDISTINCT 1 ☐										HEART WD. COLOURED 2 ☐									
LATE WD. CONSPICUOUS 3 ☐										DISTINCT ODOR 4 ☐									
DISTINCT TASTE 5 ☐										GREASY 6 ☐									
DIMPLED GRAIN 7 ☐										PITS ALTERNATE 8 ☐									
PITS 21-SERIAL, OPP. 9 ☐										TORI SCALLOPED 10 ☐									
SPIRALS 11 ☐										CALLITROID THICKENINGS 12 ☐									
PRESENT 13 ☐										ABUNDANT 14 ☐									
END-WALLS NODULAR 15 ☐										RAYS									
RAY TRACHEIDS 16 ☐										R.T. DENTATE 17 ☐									
HORIZ. WALLS THIN 18 ☐										" " UNPITTED 19 ☐									
" " WELL PITTED 20 ☐										INDENTURES 21 ☐									
END WALLS MODULAR 22 ☐										1-3 LARGE 23 ☐									
PICIFORM 24 ☐										CUPRESSOID 25 ☐									
TAXODIROID 26 ☐										1-6 PINOID 27 ☐									
K ☐										J ☐									
I ☐										H ☐									
42 ☐										41 ☐									
CUPRESSACEAE 40 ☐										TAXODIACEAE 39 ☐									
PINACEAE 38 ☐										CEPHALOTAXACEAE 37 ☐									
ARAUCARIACEAE 36 ☐										PODOCARPACEAE 35 ☐									
TAXACEAE 34 ☐										7-12 " " 33 ☐									
5-6 EPITH. CELLS 32 ☐										EPITH. C. WALLS THICK 31 ☐									
HORIZONTAL 30 ☐										TRAUMATIC " 29 ☐									
28 ☐										VERTICAL DUCTS									
BOTANICAL FAMILIES										RESIN DUCTS									
PINUS SYLVESTRIS L.										PARENCHYMA									
GENERAL										TRACHEIDS									
END-WALLS NODULAR 15 ☐										ABUNDANT 14 ☐									
PRESENT 13 ☐										CALLITROID THICKENINGS 12 ☐									
SPIRALS 11 ☐										TORI SCALLOPED 10 ☐									
PITS 21-SERIAL, OPP. 9 ☐										PITS ALTERNATE 8 ☐									
DIMPLED GRAIN 7 ☐										GREASY 6 ☐									
DISTINCT TASTE 5 ☐										DISTINCT ODOR 4 ☐									
LATE WD. CONSPICUOUS 3 ☐										HEART WD. COLOURED 2 ☐									
G. RINGS INDISTINCT 1 ☐										END-WALLS NODULAR 15 ☐									

Fig. 1. Key to the Identification of Coniferous Timbers : Specimen Card

to make special uniformity tests, while in other cases the data can be obtained in the course of ordinary experiments.

(b) *Statistical Analysis applied to Wood Bending*

A method of analysis similar to that of the "percentage-kill" used in problems of insect control has been further developed for estimating the bending quality of wood. The technique of making bends with a strap formerly required a large amount of material. For this test a combination of the "percentage-kill" method with a multiple test piece has proved especially economical. The essentials of the method are that each of a number of pieces is bent to a certain radius and the fraction which fails is noted. Other groups of pieces are bent to other radii and the failures noted. If the exploration has been made over a suitable range of radii, a picture will be obtained of the variation in bending strength from piece to piece. For, in the extreme, if there were no variation, a radius could be found below which all, and above which no, pieces would fail. As the variation increases, the radii corresponding to these two cases differ more and more, and it is possible to observe intermediate fractions of failures. If the general form of the variation is known it is possible from a few of these intermediate observations to extrapolate to the particular percentages which are of interest. For example, in wood bending the average radius is not in itself of practical use, since approximately half of any batch of sticks break in the process of bending to this radius. It is preferable to state the radius for, say, ten per cent breaks, and to find this it is necessary to explore the variability of the sticks as described above. The general form of the variation has not yet been established, but this obviously cannot be achieved until a fair amount of data has been accumulated.

(c) *The "Weakest Link" Principle*

The more variable the material, the more important becomes the principle that the weakest part determines the strength of the whole. For example, if a piece of wood is bent so that the stress at all parts of its length is the same, it will break at its weakest part. A curve of frequency of broken pieces against breaking stress for pieces 1 ft. long will thus not be the same as for pieces 2 ft. long, because the longer pieces will contain a part weaker than any given value more frequently than the shorter ones.

It follows that for destructive tests involving the weakest link (for example, tensile, bending and bursting tests and some compressive tests), the size of the test piece has an important bearing on the application of test results to practical uses. The importance of this allowance for size is illustrated by Fig. 2, in which A is a hypothetical normal frequency curve for test pieces of one length, and B the corresponding curve for pieces 10 times as long. The shift in the average, given in the figure on a scale of standard deviations,

is seen to be more than one standard deviation; also, owing to increasing skewness, the shift in other portions of the curve (for example, the 5 or 10 per cent limits) may be more or less than this. In addition, the curves for longer pieces show less spread.

The curves A and B have been drawn on the assumption that each of the longer test pieces is a random collection of 10 of the smaller lengths. This, of course, is not true for wood; it is well known that correlation exists for most properties between adjacent parts of the same test piece. This makes no difference to the principle, however, but requires a modification of the theory. To illustrate the effect of correlation, curve C has been drawn using an estimate of the correlation derived from some wood bending data. A part only of the very lengthy table necessary for the general application of the theory has so far been calculated.

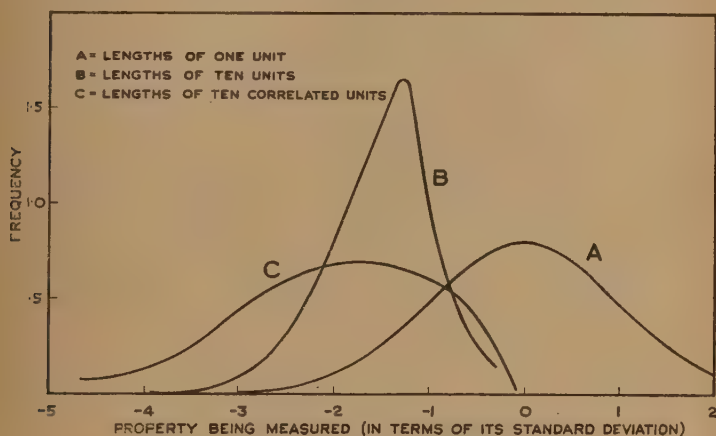


FIG. 2. *Theoretical Effect of Length of Test Piece*

Optical Studies of Planed Wood Surfaces

In last year's report mention was made of a calculation of the amount of light scattered by mirror-like inner surfaces of the cell walls which are left exposed by the passage of the plane. In considering the "finish" produced by the plane, however, it is the light scattered from the cut surface which is of interest, and this is usually neither smooth enough to be treated as a mirror nor rough enough to be taken as a perfect diffuser. The total light emitted by the cut surface at any angle is therefore a mixture of specularly reflected and diffused light, and it has now been found possible⁽¹⁾ to analyse the light into these components if it is assumed that the surface is composed of small elements or facets which are individually either perfect mirrors or perfect diffusers. These facets may be inclined at any angle to the mean surface of the material, and those

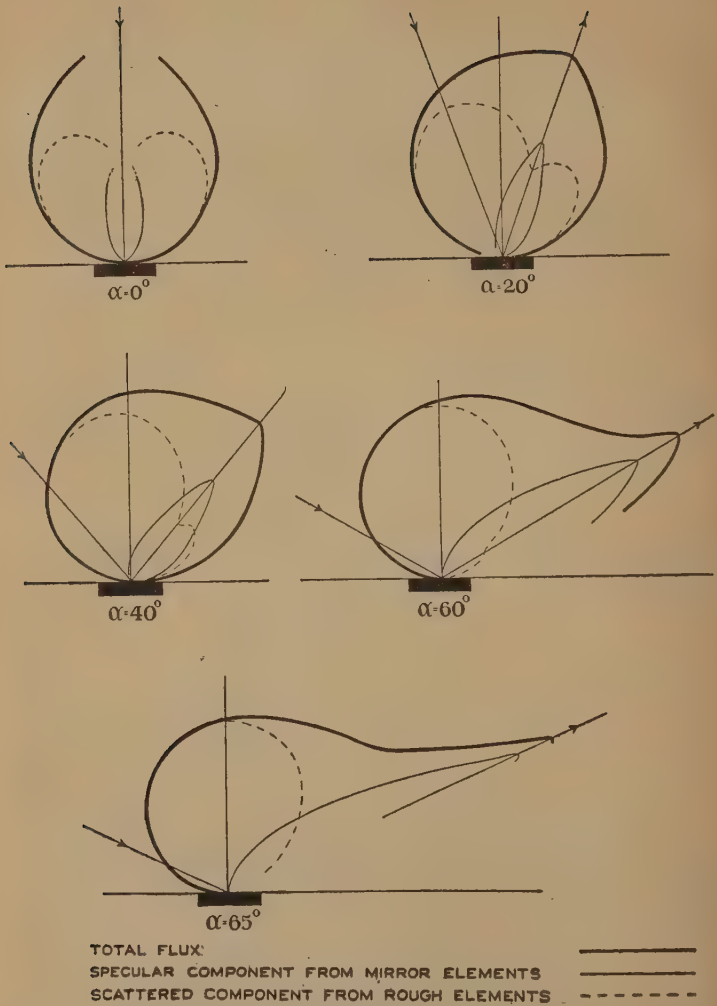


FIG. 3. *Polar Curves of Light scattered by Bristol Board under Several Angles of Illumination*

at any particular angle are assumed to be uniformly distributed over the surface. It is also possible by the analysis to find the relative areas of these facets at various angles, though the absolute areas cannot be determined from the data which so far have been accumulated.

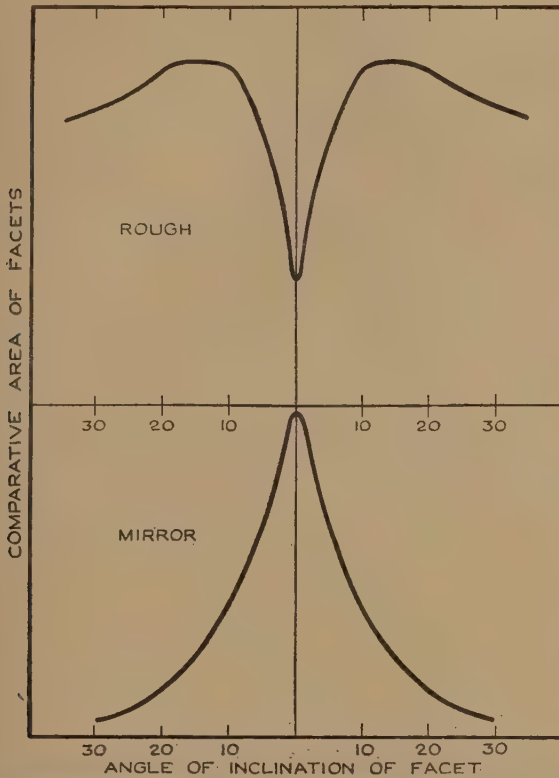


FIG. 4. *Comparative Areas of Facets at Different Inclinations to the Surface (N.B. The Areas of Rough and Mirror Facets are Plotted on Different Arbitrary Scales)*

Fig. 3 gives polar curves for the light scattered from the surface of Bristol board when illuminated at several angles α to the surface, together with the polar curves of the mirror and rough components. Fig. 4 shows the relative areas of facets set at different angles θ to the mean surface, the scale of area being arbitrary. It will be seen from Fig. 4 that most of the mirror facets are nearly parallel to the mean surface, whereas the rough facets show a minimum at this inclination. This effect is typical of a surface showing gloss, since glossy surfaces

are those which emit most light near the specular angle and must therefore contain mirror facets nearly parallel to the mean surface. A surface of magnesium oxide smoke deposited on glass was also analysed successfully, and showed that the specular components are very small compared with the diffuse components, and that the few mirror facets which exist are almost equally distributed at all angles to the mean surface.

Bristol board and magnesium oxide are both symmetrical surfaces, in the sense that a symmetrical scattering curve is obtained under normal illumination. A planed wood surface, on the other hand, usually gives an unsymmetrical curve, and the method of analysis requires modification in this case. The few measurements which have so far been made on wood surfaces suggest that the asymmetry is confined to the mirror components and that the diffuse components are symmetrical. If this is confirmed it will make easier the valuation of the "finish" of a wood surface, since the asymmetry in the specular components will probably be found to originate in the cell cavities, which are not affected by the degree of finish.

(1) BARKAS, W. W. Analysis of Light scattered from a Surface of Low Gloss into its Specular and Diffuse Components. *Proc. phys. Soc.*, 1939, **51**, 274-295.

Vibration Methods for Measuring the Elastic Constants of Wood

In last year's report, the advantages of non-destructive methods of measuring the elastic constants of wood were pointed out. Methods using strips approximately $28 \times 1 \times 0.2$ in. ($70 \times 2.5 \times 0.5$ cm.) involving (1) flexural oscillations to measure Young's modulus, E , and (2) torsional oscillations to measure rigidity modulus, G , were briefly described. Work during the past year has suggested that vibration methods merit further development.

With certain reservations wood can be regarded as having three mutually perpendicular symmetry axes, coinciding with the longitudinal (L), tangential (T) and radial (R) directions, and it can thus be treated mathematically as equivalent to a rhombic crystal system. In this system, at least nine, and possibly twelve, independent constants are needed completely to express the strain components in terms of the stress components. These twelve constants are the reciprocals respectively of the three Young's moduli, E_L , E_T and E_R , the three rigidity moduli G_{LR} , G_{RT} , G_{TL} (where the suffixes refer to the planes of shear), and six transverse moduli of the type: stress in one direction/strain in direction at right angles to it. The transverse moduli should theoretically be equal in pairs, thus reducing the number of constants to nine, but for wood it appears that these relations among the transverse moduli do not invariably apply. All these moduli have been measured previously by a number of experimenters, using, for the most part, standard testing methods, but hitherto vibration methods do not appear to have been applied to wood in spite of their distinct advantages for some

purposes. In general, it should be possible to measure all the moduli in wood by suitable vibration methods, but in practice only three, E_L , G_{RL} and G_{TL} can be measured conveniently, if the oscillations of strips having the dimensions given above are timed with a stop watch, owing to the difficulty of obtaining sufficiently long strips in the transverse directions of the grain. Since the properties connected with the longitudinal direction are also of greater practical importance than in the other two directions, it has been decided to confine attention initially to this direction.

The variation of E_L , G_{RL} and G_{TL} with moisture content has been studied in some detail on single strips of beech and Sitka spruce, and the statement made last year that there is little or no indication of any sharp breaks in the curves has received further support. In both species, G is relatively more sensitive to moisture changes than is E ; a moisture content change from 10 per cent to 30 per cent causes a change of some 50 per cent in G , but only 25 per cent in E .

The actual values of the moduli at 12 per cent moisture content, together with the corresponding densities, are given in the following table. In addition to the moduli as ordinarily calculated on unit area of cross-section of the test piece, the moduli calculated on unit area of wood water *aggregate* have also been inserted, and are distinguished in the table by "test piece" and "aggregate" at the head of the respective columns.

Species	Density (O.d. wt./O.d. vol.)	Modulus	Test piece (lb. per sq. in. $\times 10^{-6}$ *)	Aggregate (lb. per sq. in. $\times 10^{-6}$ *)
Sitka spruce	·40	E_L	2·01	6·95
" "	·37	E_L	1·78	6·63
Beech ..	·67	E_L	1·81	3·84
" ..	·60	E_L	1·54	3·62
" ..	·72	E_L	1·89	3·74
" ..	·71	E_L	2·25	4·47
Sitka spruce	·40	G_{RL}	0·116	0·402
Sitka spruce	·37	G_{TL}	0·107	0·402
Beech ..	·69	G_{RL}	0·172	0·350
Beech ..	·65	G_{TL}	0·125	0·268

* 1 lb. per sq. in. = ·0703 kg. per cm.²

This table shows that in the case of E , where alone comparison is possible, the moduli based on area of aggregate show less variation than the uncorrected moduli. On the basis of unit area of aggregate, Young's modulus for Sitka spruce is nearly twice that for beech, a fact which, of course, is not new, but which accounts for the

popularity of the former in aircraft construction. On the same basis Sitka spruce appears slightly stronger in torsion than beech.

The above vibration methods have also been used to measure E and G in strips of birch 3-ply at 60 per cent humidity (approximately 12 per cent moisture content) in which the grain in the

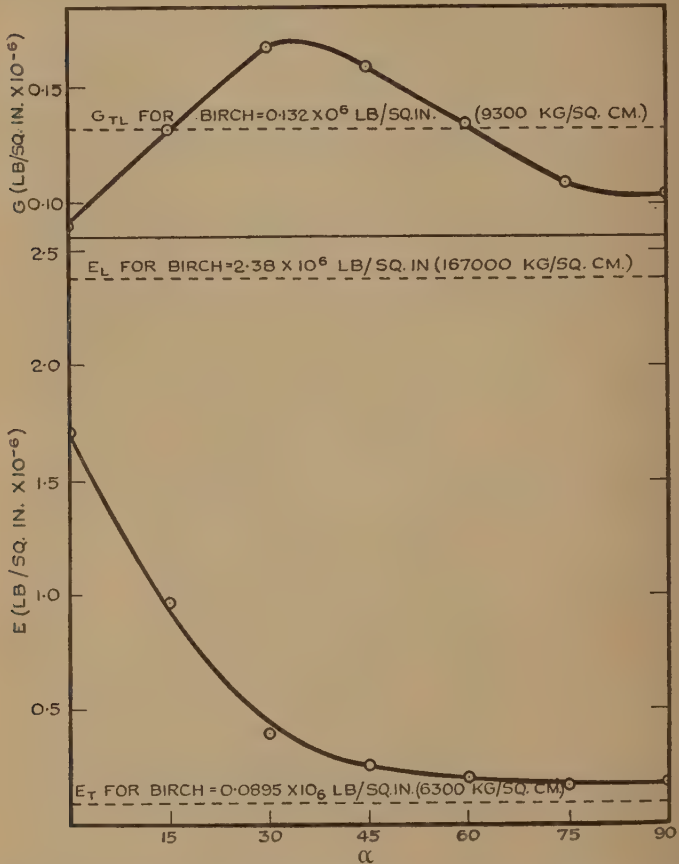


FIG. 5. Variation of Young's Modulus in Bending and Rigidity Modulus with Grain Direction in a Birch Three-ply Wood at 60 per cent Relative Humidity (Approx. 12 per cent M.C.)

outer plies lay at a number of inclinations (α) to the axis of the strip, the grain direction in the inner ply remaining, of course, perpendicular to that in the outer plies. These results are plotted in Fig. 5.

The values of either E or G for the plywood as a whole will be a compromise between the moduli of the individual plies and will be almost entirely determined by the properties in the longitudinal—tangential plane of the birch used in its manufacture, since this birch is rotary cut. The only moduli in this plane which can have an appreciable effect on the properties of the plywood are E_L , E and G_{LT} , which are shown on Fig. 5 for comparison. The agreement is particularly satisfactory for E , since the bending properties will be largely determined by the outer plies, but there will be some weakening effect of the middle ply at $\alpha = 0^\circ$ and some strengthening effect at $\alpha = 90^\circ$. This is what is in fact found, since the value of E at $\alpha = 0^\circ$ is less than E for birch, and E at $\alpha = 90^\circ$ is greater than E_T .

For convenience of humidity control, and to enable the other elastic constants to be measured, it is desirable to be able to use smaller specimens than the above.

Shortening the specimen raises the frequency of the vibrations, so that electrical methods of producing and analysing the vibration must be used. Two different methods of measuring the natural frequency of a wood specimen are being developed, from which its elastic properties may be calculated. These may conveniently be called the "forced" and the "free" vibration methods.

In the forced vibration method, alternating current, at a frequency which can be varied, forces the wood specimen to vibrate, while the strength of this vibration is recorded and measured on a cathode ray oscillograph. As the frequency of this forced vibration is varied it is observed that the vibration has a maximum value corresponding to the natural frequency of the specimen.

In the free vibration method a short piece of wood is struck a single blow at one end by a light hammer⁽¹⁾. The resulting free vibration takes place at the natural frequency of the specimen. As this vibration dies away in about 1/50th of a second, its trace on the oscillograph must be photographically recorded.

These methods also record another property of considerable interest, which is the "damping" or "internal friction" of the wood. This property is of theoretical interest, as wood is one of the most highly damped solid materials which at the same time possess high mechanical strength. It is more damped than brick or concrete, and very much more than any metal.

From the practical viewpoint the high natural damping tells in favour of wood in aeroplanes or other structures where mechanical vibrations may cause dangerous localised stresses at certain resonant frequencies.

One of the principal advantages of these methods in fundamental studies, as compared with the use of large testing machines, is that the stresses are only of the order of a few pounds per square inch and

the loading rates are much higher, thus giving less chance for the partially plastic nature of the wood to distort or mask the true elastic properties.

(1) See, e.g., GRIME, J. The Determination of Young's Modulus for Building Materials by a Vibration Method. *Phil. Mag.*, 1935, **20**, 304.

Moisture Relations of Wood

It seems probable that the work on the moisture relations hitherto carried out by the Physics Section and recently published in a special report⁽¹⁾ will have useful applications to problems connected with the use of wood under high stresses, and it may be

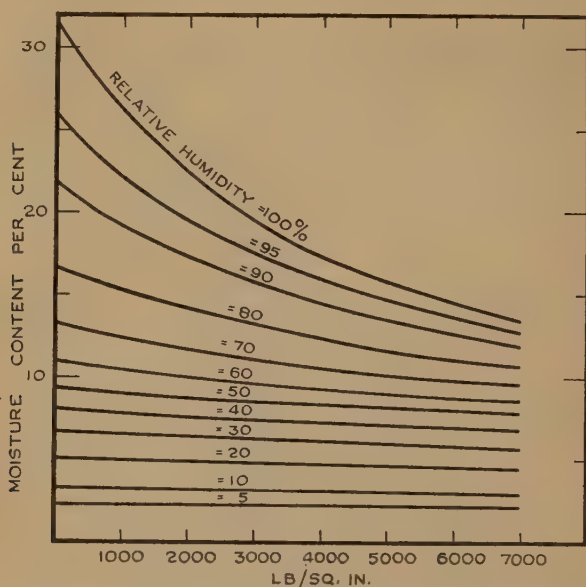


FIG. 6. *Equilibrium Moisture Content of Beech under Different External Hydrostatic Pressures*

of interest to give a brief description of some of the deductions which may be drawn from it.

When wood or any other hygroscopic material is subjected to hydrostatic pressure, the vapour pressure of its sorbed water rises, so that if the humidity of the atmosphere surrounding the wood is kept constant, moisture will evaporate and the wood will be left at a lower equilibrium moisture content than it would normally have at that humidity. If the pressure is released the moisture content will return to its normal value. These changes can be

calculated, and Fig. 6 gives the change in equilibrium moisture content with external hydrostatic pressure for the absorbing cycle of beech in equilibrium with various humidities. In practice, of course, the load is more usually applied in a single direction, but the hydrostatic component of a directional stress can always be calculated from the bulk modulus if the lateral expansions accompanying the compression are also measured. Data of this kind are available, and it has been found, for example, that a tangential stress of 250 lb. per sq. in. (17.6 kg./cm^2) at 90 per cent humidity reduces the equilibrium moisture content by about 1.5 per cent. The effects

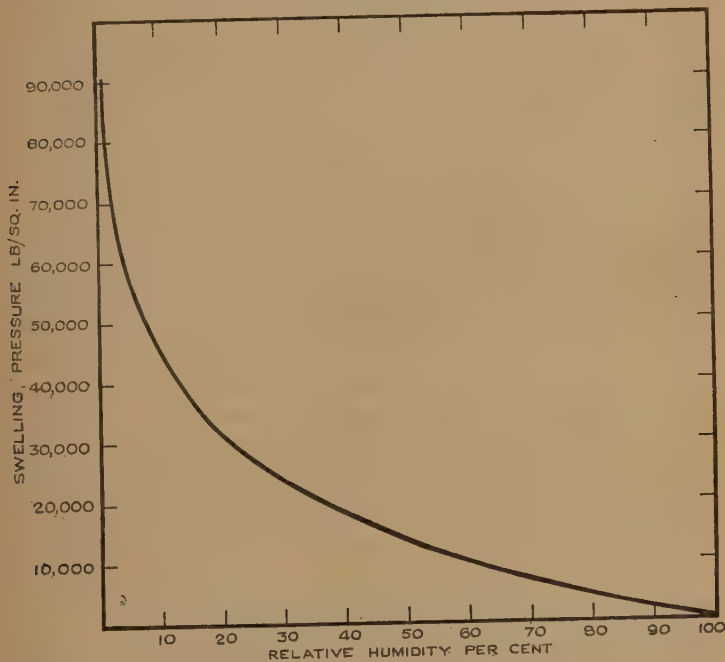


FIG. 7. *Swelling Pressure exerted by Wood Substance at Different Humidities*

of loading in the radial and longitudinal directions are not so great as this, but are appreciable. This result has a bearing on the permanent set experiments carried out by the Seasoning Section and discussed later in this report (page 24).

The reduction in moisture content arises from the fact that wood exerts a swelling pressure when it tries to take up moisture. The swelling pressure, originally deduced by Katz, is numerically equal to the hydrostatic pressure required to prevent wood from

taking up moisture when it is transferred to a saturated humidity. The pressure exerted by wood, initially in equilibrium with different humidities, may be seen from the curve in Fig. 7. In many of the laminated wood products now being made, layers of initially dry wood are cemented together under pressure with a synthetic resin of the bakelite type. It is frequently assumed that this process renders the wood waterproof, so that shrinking and swelling are prevented or greatly reduced. Tests have been made which indicate that the resin only retards the rate of uptake of moisture but does not render the wood inherently less hygroscopic. Thus, if the resin is effectively to prevent swelling of initially dry wood, it must exert the very high hydrostatic pressures given in Fig. 7, and must itself therefore be in a state of tension. Since such resins usually possess a comparatively low tensile strength, it will be seen that humidity changes of long duration may cause the breakdown of the resin re-inforcement. Considerable importance must therefore be attached to any method whereby these stresses may be studied. A preliminary survey has been made this year of the possibility of calculating these internal stresses in laminated sheets, and it seems probable that considerable insight can be gained from a study of moisture relations. For example, it was possible to calculate from the single fact that a particular specimen of impregnated and laminated beech had a moisture content of 9.4 per cent instead of 10.9 per cent at 60 per cent humidity that the wood was under a pressure of approximately 3,500 lb. per sq. in. (246 kg./cm.²).

It should be noted that, although the external volume of the wood may vary under load, the wood-water aggregate at a particular *equilibrium* moisture content always occupies nearly the same volume, whether or not it is under load. Thus, if compressed laminated wood is found to have suffered a *permanent* reduction in external volume compared with normal wood at the same moisture content, this reduction must be at the expense of the void spaces in the structure. The deductions regarding the internal hydrostatic stress in such materials is also independent of any distortion of the material which may take place, and it is not infrequently found that the swelling perpendicular to the laminations is very much greater than that of the natural material, the reduction in swelling being imposed only in the direction parallel to the laminations by the continuous interply filaments of resin.

Owing to the comparatively small changes in moisture content which occur even under large loads, the internal stresses have not so far been calculated with precision, but in the coming year it is hoped to develop the method further.

(1) BARKAS, W. W. Recent Work on Moisture in Wood. *Spec. Rep. For. Prod. Res., Lond.*, 1938, No. 4.

Variation of Thermal Conductivity and Diffusivity with Moisture Content

The variation of conductivity and diffusivity with moisture content is of importance in the theory of drying and other processes effected by heat. Measurements of the two properties have hitherto had to be made separately and not always under comparable conditions. There is, however, a method recently perfected by Vernotte⁽¹⁾ which provides a simultaneous measure of both and which, with slight modification, has been successfully used in this Laboratory on beech and Sitka spruce.

The advantages of the method are a very small rise of temperature and the use of the same pieces of wood for a whole cycle of humidities. It is a characteristic of the method that a constant flux of heat is maintained instead of, as is more usual, a constant temperature. This has the advantage that perfect thermal contact between two wood surfaces is not essential; it is this requirement which, in other methods, prevents the same pieces of wood being used at different humidities owing to the slight deformations which occur with change of moisture content. A useful check on the results is provided by the calculation of the volume specific heat as the ratio of conductivity to diffusivity. Separate measurements of this are available, and the quantity must be independent of grain direction.

The results so far obtained confirm the previous finding from this Laboratory that the diffusivity increases with fall in moisture content. The conductivity tends to decrease with fall in moisture content, though the changes are not so great. The values of both conductivity and diffusivity, in the direction parallel to the lengths of the fibres are from two to three times as great as those in the radial or tangential direction.

Because the diffusivity coefficient is a function of conductivity, specific heat and density, and because each of these three properties is influenced by moisture, it is not likely that measurements of diffusivity will approximate at all closely to the simple relationship with moisture content which some workers in this field predict.

⁽¹⁾ VERNOTTE, P. Détermination simultanée de la Chaleur spécifique et de la Conductibilité thermique des Isolants. Méthode du Signal. *C.R. Acad. Sci., Paris*, 1937, **204**, 563.

Relations between the Moisture Content of Wood and the Surrounding Hygrometric Conditions

The work of re-determining the moisture content—humidity equilibrium curves for wood at various temperatures continues. The technique, described in the Report of the Forest Products Research Board for the year 1937, of weighing the samples without removal from the kiln has been further improved. Additional investigations into the variations of moisture content equilibrium values, not only between species but within a species, have shown the

importance of determining every point with several independently selected sets of samples, and only by these means can curves be obtained that can be used with confidence for general purposes. Much of the year has been spent in obtaining these check points at various humidities for temperatures ranging from 10° C. (50° F.) to 75° C. (167° F.), and it is anticipated that this work will, of necessity, be continued for a long time. In co-operation with the Ditton Laboratory of the Food Investigation Board, equilibrium tests at low temperatures have been arranged. At present, a series at 4.5° C. (40° F.) is in progress and will be followed by tests at freezing point.

The important work of ascertaining the limiting moisture gradients that can be left in dried timber without affecting the stability of the material in service has been extended to English oak, 1 in. thick, and elm, 2 in. thick. It was shown in last year's report that with 1-in. Polish oak intended for furniture manufacture, an average moisture content of 12 per cent was quite satisfactory, even when accompanied by a gradient of 3 per cent, that is, when the outer layers of the board have a moisture content of 10 per cent and the centre portion 13 per cent. Tests on the 1-in. oak are completed, but the figures have not been analysed. Experiments on elm are still in progress.

The investigation which aims at finding a method of treating wood so that the movements accompanying moisture content changes resulting from variations in the surrounding atmosphere may be reduced has been continued throughout the year. New substances, which appeared to offer possibilities in this direction, have been tested, but so far no material has shown such promise as sorbitol, to which reference has been made in previous reports. Soaking in an aqueous solution of sorbitol was found to be an effective method of treatment in the case of oak veneers, and was repeated using green beech and oak boards $\frac{1}{2}$ in. and 1 in. thick respectively. The experiments on the sorbitol-treated beech boards have been completed⁽¹⁾, and it was found that the movement was appreciably reduced, provided that a fairly high concentration (15–20 per cent by weight) of sorbitol was present. In the case of oak boards, the experiments are still in progress but are sufficiently far advanced to demonstrate that the effects are superior to those obtained in beech. The presence of about 20–25 per cent of sorbitol (by weight) reduces the movement by 40–50 per cent.

The importance of knowing the movement or "working" values for different untreated timbers needs no stressing, for the choice between one or another may depend on the relative movements that will occur. Measurements of "working" have been made by a variety of methods for a long time, but only during the past year or so has the problem received systematic study with regard to variations within a species. For example, tests on 24 pieces of beech, cut from the same piece of wood and end-matched, indicated

that the standard deviations (expressed in thousandths of an inch per foot width of timber) were 3 in the radial direction and 5 in the tangential direction of the grain. With this as a basis, the extent of the variation within a consignment from one growth locality is being determined. From such experiments as these it is hoped to evolve a standard technique for measuring "working" and for expressing the results in such a way that the degree of possible variation may be taken into account in applying the figures to practical problems.

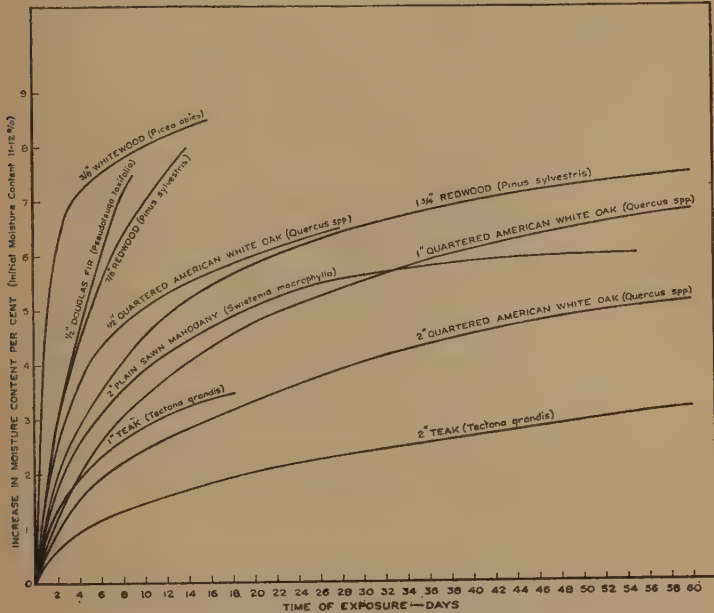


FIG. 8. The Absorption of Moisture by Dry Timber when stored in a Damp Situation

(25° C. (77° F.) and 90 per cent Humidity)

Frequent inquiries are received concerning the rate at which dry timber will absorb moisture if stored in a damp place. The problem is of immediate application in the case of new buildings, and is sometimes not without importance where repairs and alterations are being made in museums and workshops where valuable decorative woodwork is in storage. Tests on the absorption rates of oak, mahogany, teak, red deal, white deal and British Columbian pine in thicknesses varying from $\frac{3}{8}$ in. to 2 in. have been completed, and representative results are shown in Fig. 8. The samples were first dried to a moisture content of 11-12 per cent

and were then freely exposed to the air in a chamber maintained at 25° C. (77° F.) and 90 per cent humidity. As the air circulation in the chamber is fairly brisk the absorption rates shown probably approach the maxima attained in practice. If the timber were bulk-piled, sheeted over or otherwise protected from the air, the absorption rates would be very much slower. For instance, 1-in. jarrah flooring bulk-piled in an open-sided shed in winter absorbed less than 3 per cent moisture content (from an initial moisture content of 12 per cent) in 90 days (see Fig. 4 in the Report of the Forest Products Research Board for the year 1935.)

When dry timber is to be stored for long periods, or alternatively when air-dried timber is to be further seasoned to make it suitable for indoor use, it is very desirable that the storage conditions should be such as to correspond to a moisture content of about 12 per cent. In a high humidity climate like that of this country, the required conditions can generally be attained by slight heating. A simple apparatus has been devised which automatically controls the air conditions. Fig. 9 illustrates the controller. The block of wood forming the sensitive element is first conditioned to the desired moisture content, and the screw so adjusted that the micro-switch is just in the "off" position. A slight increase of moisture in the block results in an expansion across the width. This closes the switch, which brings the heaters into play, either directly or through a relay, or alternatively by operating a magnetic or motorized valve in a steam or hot water circuit. A rise in air temperature lowers the humidity, thus causing the wooden block to dry and shrink and so break the switch. Under test in a small room at the Laboratory, the controller maintained a moisture content constant to within $\frac{1}{2}$ per cent over a period of nine months. In December, the "on" and "off" temperatures were 10·8° C. and 14° C. (51° F. and 57° F.), and in June, 20·6° C. and 23·8° C. (69° F. and 75° F.), respectively.

In co-operation with H.M. Office of Works, the moisture content conditions applicable to timber in the new telephone house at Glasgow are being determined during the course of erection. As a comparison, tests are being made simultaneously in London telephone exchanges at Bishopsgate and Waterloo, which are thoroughly matured buildings. The Laboratory is indebted to the Post Office engineers for their assistance in this work. Tests similar to those undertaken in the National Gallery some years ago, concerning the influence of atmospheric change on panel paintings, are now being conducted in the Tate Gallery. In view of the comparatively recent extensions and alterations, the two series of moisture content figures will prove of considerable interest.

The first general investigation into the effects of permanent compressive set caused by restraining the expansion of wood during the absorption of moisture has been completed, and the results published⁽²⁾. It was found that when the clamps which had

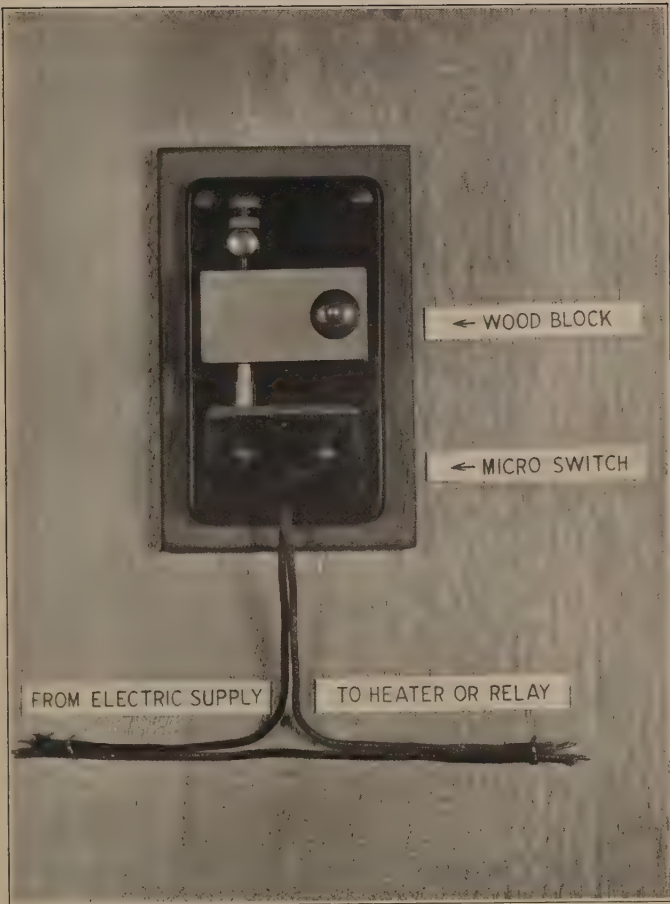


FIG. 9. *Wood Block Controller for maintaining Conditions of Constant Moisture Content in a Timber Store*

restrained movement were withdrawn there was an immediate expansion due to the elasticity of the compressed wood, and this was followed by a slow creep to a constant size which was less than that of the unrestrained piece. The elastic recovery is about a quarter of the difference between the size of the clamped piece and that of the unrestrained one, the creep recovery is of the same order, about half the total difference remaining as permanent set. The word "permanent" requires qualification, as the set can be partly reduced by exposing the wood to a humidity higher than that at which set occurred. It is of interest that the moisture content attained by a panel under restraint is less than that of an unrestrained matched piece under the same atmospheric conditions. This is in agreement with Katz's thermodynamic equation for the swelling pressure of hygroscopic materials and is discussed above under the heading of "Moisture Relations" (p. 18).

(1) BATESON, R. G. Sorbitol in Wood Treatment. Further Experiments on Shrinkage and Swelling Behaviour. *Chem. Tr. J.*, 1938, **103** (2668), 26-27.

(2) KNIGHT, R. A. G., and NEWALL, R. J. Permanent Set of Timber. *Forestry*, 1938, **12**, 125-135.

Instruments for the Rapid Determination of the Moisture Content of Wood

During the year, a British-made electrical moisture meter has been calibrated for six species of timber at the request of the manufacturers. Further tests on an extended range of timbers are in progress.

Steamed Timber

Further work has been carried out on the properties of steamed timber. In addition to lowering the moisture content—humidity equilibrium values, steaming appreciably increases the movements or the "working" of oak, both in the radial and tangential directions. Beech, however, moves slightly less tangentially, the radial "working" remaining the same. The treatment appears to have very little effect on the movements of elm. These findings refute the common belief that steaming makes timber more stable in use. The colour changes of oak and beech resulting from steaming have been described in earlier reports, but work has previously been confined to treating the timber in the freshly converted or green state. Tests on air-dried and kiln-dried beech and oak have shown that somewhat similar colouring effects can be obtained with seasoned timber. Beech, however, colours best when steamed green; in fact, when treated in the kiln-dry state, the characteristic pink is lost and replaced by a definite brown. Oak, on the other hand, assumes its most pleasing colour when steamed after air- or kiln-drying, and the degrade through splitting is less in the latter case.

Kilns and Kiln-seasoning

(a) Intermittent Kiln Operation

Further attention has been given to the relative merits of continuous and intermittent kiln operation in the case of 2-in. oak. Using a mild schedule, a load was dried in a fan kiln by the continuous operation method in 84 days. With a strictly comparable treatment, the intermittent process occupied 125 days. The total-time ratio was thus 1 to $1\frac{1}{2}$, but on a kiln-running time basis the ratio was reversed to nearly 2 to 1, for the kiln was run under steam and power for 10 hours each full week-day and for 5 hours each Saturday, the plant being shut down every Saturday afternoon and Sunday. This method of operation appeals to many users when steam is normally available only in working hours.

(b) Influence of the Thickness of the Piling Stick on the Drying Rate in a Kiln

In a kiln of given cubic capacity, the greater the spaces between the rows of timber, the smaller will be the volume the kiln can hold, so that, other things being equal, the output varies inversely as the thickness of piling stick. In practice, however, not only the volume of timber held, but the power required to produce a strong uniform air flow, and the variations in the drying rates that will inevitably occur, are factors which govern the output per kiln and the drying costs. Tests have recently been carried out to determine the effect of size of stick on the drying of loads of 2-in. green beech. The piles were built respectively with $1\frac{1}{2}$ -in., 1-in. and $\frac{1}{2}$ -in. piling sticks, the loads were dried according to the recommended schedule for beech, and an air speed of $1\frac{1}{2}$ ft. per sec. was maintained between the rows. It was found that this air speed could be obtained in all cases with virtually no difference in the power consumed by the fans. The results of the tests are given in tabulated form below, where for purposes of comparison it has been assumed that the kiln could accommodate 100 cu. units of timber when piled with 1-in. sticks.

Thickness of stick in inches	Time in days required for drying planks on the air outlet side of the pile to an average of 12 per cent moisture content	Timber volume in cu. units	Output per 24 days in cu. units
$\frac{1}{2}$	27	120	106.7
1	24	100	100
$1\frac{1}{2}$	$22\frac{1}{2}$	85.7	81.4

These results indicate that by using $\frac{1}{2}$ in. thick piling sticks the output may be increased, and at first sight it would appear that a definite saving would result from their use, particularly if material thinner than 2 in. were to be dried. The advantages of using $\frac{1}{2}$ -in. sticks were, however, considerably offset by the fact that the pile built with these sticks distorted badly during drying, and distortion of individual planks was in some cases severe. Secondly, piling sticks as thin as $\frac{1}{2}$ in. were too fragile for normal kiln use, and the actual operation of piling was rendered difficult. Although it is realised that these results will be affected by such factors as air speed, initial moisture content, thickness and refractoriness of the timber, etc., yet it is felt that no advantage is to be gained from the use of piling sticks thicker than 1 in., whereas sticks as thin as $\frac{1}{2}$ in. cannot be recommended for general use.

The Drying of Wood in a High Frequency Electric Field

As a result of claims by workers in the U.S.S.R., in which it was stated that timber could be dried from the green condition in a matter of minutes by exposing it to a high frequency electric field, the Laboratory decided to undertake some preliminary tests, in conjunction with the National Physical Laboratory, to discover the practical possibilities of the method. Accordingly the National Physical Laboratory is testing samples of timber, conditioned to various moisture contents at this Laboratory, with a view to determining the optimum frequency, voltage, etc., for satisfactory drying. When these results are available, larger scale work is contemplated, more particularly with a view to gauging the economic possibilities of this method of drying.

Alterations and Additions to Plant

The re-construction of the constant humidity rooms has been completed, and all five compartments are in general use. Each room is 5 ft. 9 in. wide and 18 ft. long and contains large adjustable racks for the samples and a well-lit table for experimental work. Air movement is maintained by a fan, and the temperature is regulated to 25° C. (77° F.) by steam coils and electric heaters under thermostatic control.

In the rooms maintained at 90 per cent, 75 per cent and 60 per cent humidity, humidification of the air is necessary, this being obtained by the atomization of water by compressed air, the sprays being controlled automatically. At 30 per cent and 45 per cent humidities, drying of the air is necessary, and a silica gel plant is used. This is equipped with separate blowers to supply air to each room, a third blower for regenerative purposes, and an auxiliary cylinder of gel for use whilst the main cylinders are under regeneration. Control is, of course, automatic. It is essential that these constant humidity rooms should indeed give constant conditions so that they can be used with confidence and the certainty that experimental results obtained by their use will be repeatable in so

far as the conditioning of samples is concerned. Stoppages consequent upon minor breakdowns of control gear, sprays, heaters, etc., must therefore be avoided as far as possible. A regular maintenance system has been arranged, which not only covers the plant itself, but ensures that the control gear is functioning correctly and is not permitting drifts to higher or lower conditions, as these instruments are prone to do. One check on the uniformity of conditions is the weights of thin and sensitive panels of wood kept freely exposed in each room. The maximum differences in moisture content of the panels during the last quarter of the year have been :—

Constant humidity room at :—	90 per cent relative humidity	75 per cent relative humidity	60 per cent relative humidity	45 per cent relative humidity	30 per cent relative humidity
Moisture content fluctuations of the panels :—	·25 per cent	·25 per cent	·15 per cent	·15 per cent	·1 per cent

The sixth room, intended for variable humidities, is partially constructed, and the design of various special fittings has been completed. This room should be in operation early in the new year.

Protective Coatings for Timber

Tests on the moisture-proofing qualities of various paints and finishes for wood have been continued, particular attention being given to the degree of uniformity of the results. The efficiency of a paint is expressed as :—

$$\frac{B - P}{B} \times 100 \text{ per cent.}$$

where B is the moisture absorption of an unpainted panel and P that of a matched painted panel, both quantities being referred to standard times. No paint or covering has yet been found that is more than a retardant to the passage of moisture. The efficiencies of a few commonly used materials are tabulated below; the values are for a fourteen-day exposure to controlled damp conditions (90 per cent humidity, 25° C. (77° F.)).

Bituminous paint	..	..	..	87 per cent
Enamel	..	..	..	73 "
Aluminium in spar varnish			..	64 "
Lead paint	}			
Oil paint		..	..	60 "
Shellac	..	..	..	49 "
Spar varnish	..	..	..	30 "
Pink primer (one coat)		..	..	22 "

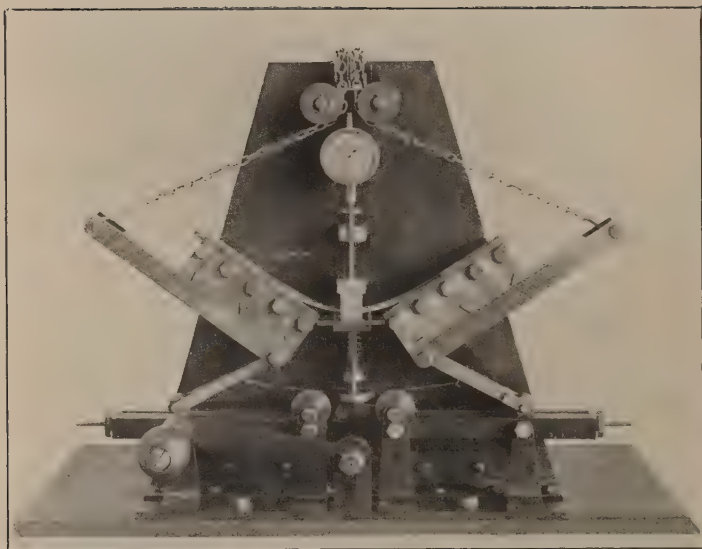


FIG. 10. *Working Model of Lever Arm Bending Machine adapted for determining the Limiting Radius to which thin Laminations may be bent*

Boiled or raw linseed oil and some of the refined creosote type of stains were found to be virtually useless. These trials were made on standard samples $\frac{1}{4}$ in. thick, and the effect on other thicknesses is being tested.

Wood Bending

Full-scale bending tests have been carried out during the year on English oak, Continental beech, and robinia, and a small-scale test has been made on Port Orford cedar. The oak bent readily and well, but was somewhat troublesome when knots were present. It was also found that bends made from air-dried material of this species $1\frac{1}{2}$ in. thick could be "set" at a temperature as high as 150° F. without checks developing, provided that the time of exposure to such conditions did not exceed about 3 hours. The Continental beech also bent readily but for bends of small radius was rather more prone to compression failure than previously tested home-grown material of similar quality. Both the robinia and Port Orford cedar were found to possess excellent bending properties comparable with such well known woods as beech or ash, and can, therefore, be recommended for use for bent work.

A study is being made of the conditions and methods most suitable for the setting of bends, and a steam-heated metal form has been made and installed on which bends similar to those of many standard type chair legs can be made and "set" to a radius of about 50 in. The movements of bends after setting and on exposure to fluctuating atmospheric conditions are also being studied, and at the request of a firm of furniture manufacturers the movements of certain bent chair parts, when exposed to tropical conditions have been examined. It was shown that after a comparatively short exposure to warm, humid conditions such as are likely to be experienced in tropical regions, the bends opened out to such an extent as seriously to distort the framework of the chair in which they were incorporated.

A working model of the lever arm type of bending machine has been made and exhibited. Modification and additions were later made to this machine so that it could be used as a standard machine for determining the limiting radius to which thin laminations might be bent (Fig. 10). A large number of tests have been made with this machine, which has proved to be well suited for the purpose required. The influence of such factors as moisture content, temperature, grain direction, etc., on the bendability of laminated wood is being investigated in this manner, and it is anticipated that, from a suitable analysis of the data so obtained, an estimate may be made of the percentage of breakages likely to occur when bending such pieces in any given state to specified radii of curvature.

A rubber bag type of press for bending and gluing laminated wood under a vacuum or at high pressures and temperatures has been constructed, and from preliminary tests promises to give

satisfactory results. It is hoped in this apparatus to produce a variety of built-up and laminated bends, the strength and other properties of which may be tested and compared with similar bends made with solid wood.

A greatly improved machine capable of making bends across, as distinct from along the grain, has been built and tested with good results. It has been found possible to bend and "set" softwoods and oak, 1 in. thick, to a radius of 3 in. successfully in a total period of about three hours. It still remains to determine the suitability of such bends for incorporation in various designs of furniture, etc.

Testing of Structural Timber

During the past year work has been concentrated on the definition of grades of Baltic redwood timber to which safe working stresses can be allocated. Examination of building codes, handbooks, etc., showed that calculations of the strength of joists, rafters, and similar structural members of this species had been based on a working stress in transverse bending which, though inconsistent, was generally of the order of 800 lb. per sq. in. (56·25 kg./cm.²). A grade of timber capable of carrying this stress with safety has therefore been defined.

In the previous year tests were completed on 120 2 × 6-in. joists, and a method of measuring knots was established which gave a fairly well defined relationship between knot size and strength. During the past year tests have been completed on 120 joists of each of the following sizes: 2 × 4 in., 2 × 8 in., 3 × 9 in.

Analysis of the results of these tests has shown that the critical factor determining the strength of joists is the maximum size of knot on the narrow face, or edge, of the member, especially where this knot is placed on the side in tension.

The more efficient way to use timber is with the largest knots on the compression edge, but as it cannot be assumed that this will be done in practice, the less efficient method must be adopted in making tests the results of which will be used in calculating the limiting size permissible.

For a safe working stress of 800 lb. per sq. in. in transverse bending, the maximum permissible diameter of knots on the edge must not exceed approximately nine-sixteenths of the "scant" width of the edge. The "scant" dimension, assumed for Baltic redwood to be $\frac{1}{8}$ in. less than the nominal dimension, allows for variation in sawing and for reduction due to shrinkage. Thus, for members nominally 2 in. and 3 in. in width, the maximum size of knots on the edge is respectively $1\frac{1}{8}$ and $1\frac{11}{16}$ in.

For an equal effect on the strength, knots on the wide face must be very much larger and, for an 800 lb. f. grade, would be considerably greater than any which occur in trees grown under normal forestry conditions. As a precautionary measure, to guard against abnormally large knots on the wide face, the size of such knots should

be limited to one-quarter the width of the face. The effect of a knot of this size would generally be less than that of a knot of the limiting size on the edge.

The weakening effect of a knot is due to the disturbance of the fibres round the knot, and therefore the condition of the knot, whether tight and sound, loose, decayed or removed, is immaterial. The size of the knot is, however, a convenient method of assessing the amount of this disturbance.

The limitations to the size of the knots apply throughout the length of any piece, since the piece may be cross-cut before use, thus locating a bad knot in a position where it will have a maximum effect.

A report on this work is now being prepared for publication.

Strength of Home-Grown Timbers

Tests have been carried out on one consignment each of willow (*Salix viridis*) and birch (*Betula alba*) and on two consignments of black Italian poplar (*Populus serotina*).

Tests of Home-Grown Poles

An investigation of the strength properties of poles of home-grown western red cedar, *Thuja plicata*, has been carried out for the Forestry Commission. The figures for strength and density of the timber were appreciably lower than the recorded values for poles of the same species grown in Canada. They were also lower than those for Baltic redwood in pole form as tested previously in the Laboratory. Owing to their greater taper however, the home-grown western red cedar poles were equal in strength to Baltic redwood poles of the same top diameter.

Developments in Methods of Strength Testing

The tests to compare the strength and stiffness of timber under bending loads by centre and four-point loading methods, outlined in the Annual Report for last year, have been completed. For beech and Scots pine, both green and air-dry, it was found that the four-point loading method gave values of equivalent fibre stress at maximum load lower by approximately 8 per cent in the case of Scots pine and 5 per cent in that of beech than the centre loading method. The true modulus of elasticity, as obtained by four-point loading, was higher by 22 per cent in the case of Scots pine and 18 per cent in that of beech than the apparent values as obtained by centre loading. These differences in the modulus of elasticity, which are due to the neglect of the influence of shear in the centre loading test, agree very closely with the theoretical values.

Further tests have been made to determine the influence of reduction of the size of test piece on the recorded strength properties. In the case of the hardness it has been found that there is a tendency for the denser hardwoods to split if the width of the specimen is

reduced below five-eighths of the standard value. The effect of reduction on values from shear and cleavage tests are now being investigated.

Box Testing

At the request of the Ministry of Agriculture and Fisheries some tests have been started on cartons for half-dozen and one-dozen eggs in connexion with the National Mark Scheme. The chief points to be investigated are the protection afforded to the eggs, the resistance to pilfering, and the fit of the cartons in the standard outer containers. Most of the cartons submitted in the first instance required modification in dimensions in order to fit the standard containers, and only two designs offered reasonable resistance to pilfering, the remainder permitting the eggs to be changed in from 40 seconds to 2 minutes. These points were taken up with the manufacturers and in consequence further cartons embodying the necessary modifications are being tested. From results already obtained it appears that while cartons in fibreboard outer containers generally do not attain the standard of protection of the new egg pack devised at the Laboratory, they are superior to the original standard pack of the Ministry of Agriculture and Fisheries. The work is continuing.

Several series of tests have been carried out for manufacturers, including tests of materials such as fibreboard, a special maizeboard, etc., and also tests of containers for eggs, canned milk, soap, telephone instruments, whisky bottles, etc.

Tests were made on two patterns of carton for respirators, submitted by the Air Raid Precautions Department of the Home Office. In addition to making the desired observations as to the relative merits of the cartons submitted, the Laboratory was able to prepare a design for a new pattern of carton, smaller in size and therefore more suitable for the pocket, stronger, and very much cheaper than those submitted.

Abrasion of Floors

Standard abrasion tests for determination of the suitability of timber for flooring have been carried out on the following timbers, of which the two last-named were tested on behalf of manufacturers :—

Tallowwood	..	<i>Eucalyptus microcorys</i>	..	Rift-, intermediate- and slash-sawn.
Gurjun	..	<i>Dipterocarpus</i> spp.	..	Rift- and slash-sawn.
Merbau	..	<i>Intsia bakeri</i>	..	Rift-sawn.
Greenheart	..	<i>Ocotea rodicæi</i>	..	Rift- and slash-sawn.

Of these timbers, gurjun and merbau may be classed as heavy and greenheart and tallowwood as very heavy. Under test their resistance to wear proved correspondingly high. The surface of the

greenheart remained quite smooth, and apart from a tendency to splinter at the edges of the blocks, the wood reacted similarly to the best flooring timbers. In the case of the tallowwood, interlocked grain caused the surface of a few rift- and intermediate-sawn blocks to roughen slightly, thus bringing the timber into a classification slightly below the best. With the merbau and the gurjun surface-roughening was more frequent, being particularly marked with the slash-sawn gurjun. On this evidence merbau and gurjun, when rift-sawn, belong to the large group of good-class flooring timbers which fall somewhat short of the highest standard when exposed to either industrial traffic, as represented by steel-tyred trucks, etc., or to very heavy foot traffic.

It was reported last year that the London Passenger Transport Board had kindly consented to afford facilities for flooring panels of various timber to be placed on sites on its premises. Six panels were laid during April in a passage at a station on the underground railway. As sufficient length of passage to lay all the panels in one group was not available they were laid in two series of three, in the same passage but separated by an entrance. The two series are therefore exposed under identical conditions except that the traffic passing over the first set is about half that passing over the second set. Counts show that approximately 45,000 people a week are passing over the first set of panels, which comprise gurjun, Tasmanian oak and jarrah and 95,000 over the second set, which are of Continental oak, birch and maple.

At the end of the year, *i.e.* after nine months' service, the surface of these timbers is showing wear very similar to that observed in the standard abrasion test of the Laboratory. Further panels will be laid when the present panels are due for renewal.

Another experiment, carried out by request, was to determine the effect of repeated applications of oil to wood flooring. The timber used was American oak and comparative tests were made between panels treated once only with oil and panels treated at intervals during the test. The repeated application of oil was found to retard the surface breakdown to some extent, though there was no change in the form of the ultimate failure. On this evidence, regular treatment with oil helps to maintain the surface of floors carrying relatively light traffic, but makes little difference when the traffic is so heavy as to cause more rapid breakdown of the surface.

Woodcutting Research

(a) The Principles of Woodcutting

Further studies of the mechanics of cutting have been made during the year on the lines mentioned in the report for 1937. An important aspect of the work was the determination of the mathematical relationships between variables in the cutting conditions, the geometry of the cut material and the forces imposed on the

wood by the cutter. These data provide a means of determining theoretically the conditions best suited to the physical properties of a timber, so that the variables can be controlled accordingly.

The reaction of the wood to the knife in curvilinear and rectilinear cutting has been studied by cinematographic and other methods at different cutting speeds, cutting angles and depths of cut. The cutting process consists, as with other materials, of separation of the wood substance, at the plane described by the cutting edge, and deflection of the separated material. Between the limits of the cutting angle that can normally be employed in wood-cutting machinery, the separation appears to be due to rupture of the material under intense compression in the immediate vicinity of the knife edge. The separated material is forced up the face of the knife as the cutting edge penetrates further into the wood and a chip is formed. The deflection causes generally a succession of local compression failures in the separated material, and in certain cases minor riving may occur ahead of the knife. The resistance of the wood to deflection consists of a force acting normal to the knife face and a force parallel to the face arising from frictional resistance to movement between the separated material and the knife. The sum of the components of these forces in the direction of motion of the knife, and the force required at the cutting edge to overcome the ultimate compressive strength of the wood and produce rupture constitute the load on the knife. The magnitude of these forces depends not only on the physical properties of the wood but on the relative speed of the knife and wood, condition of the knife edge, cutting angle, etc., and so can be controlled by variation of the latter factors. The length of time during which the forces are acting, and the number of separations in a given time or length of material in relation to the amount of wood removed per cut, are dependant on the feed and spindle speeds, number of cutters, depth and other dimensions relating to the cut. This study has formed the theoretical basis for establishing relationships between the variables in the cutting conditions and the behaviour of the wood as regards its energy absorption, resistance to feeding and quality of finish.

The practical aspect of the work is described in the following account of a full scale investigation in rotary planing. The experiments were carried out on the planing machine shown in Fig. 11, mentioned in the report for 1937. The general design of the machine does not depart from ordinary commercial practice, but it has certain additional features for purposes of research, viz., provision for alteration of the cutting angle and the spindle speed of the cutterblock. The feeding mechanism is electrically driven, has nine speeds and is combined with a hydro-mechanical device which records on a moving chart the force required to feed the timber during planing (Fig. 12.) The record takes the form of a "work done" curve and shows the resistance to movement due to friction

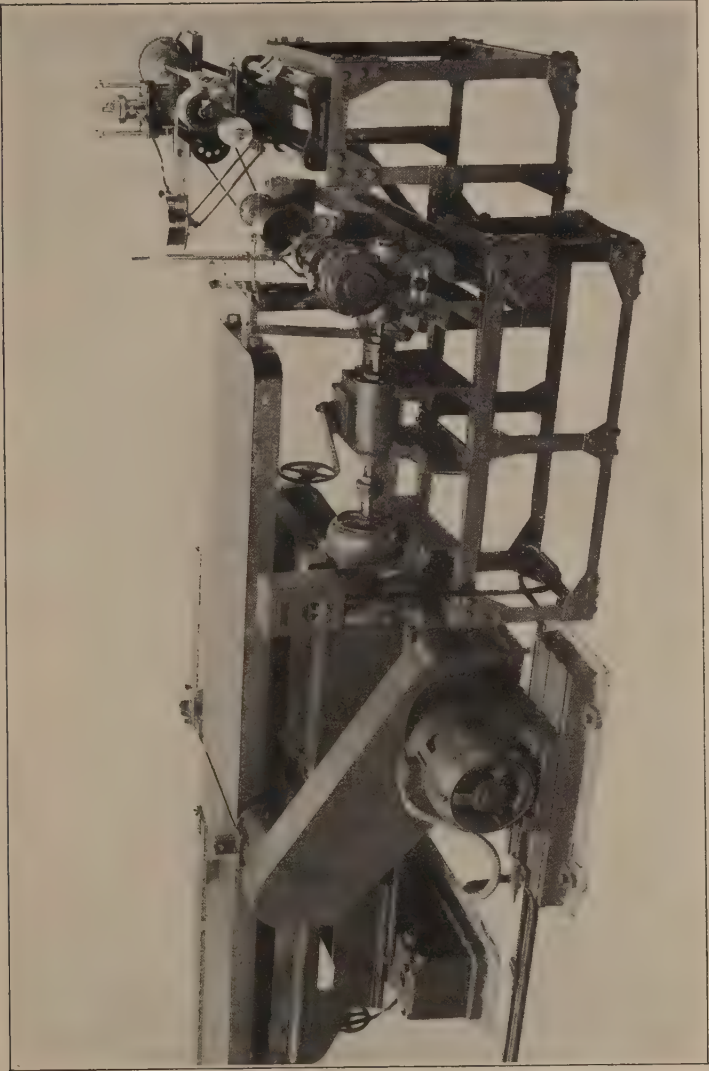


FIG. 11. Planing Machine for Experimental Work

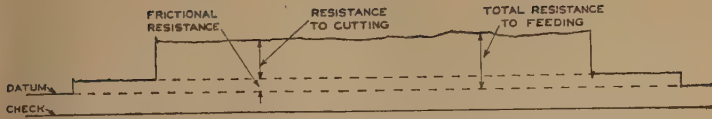


FIG. 12 *Autographic Record of Feed Resistance in Planing*

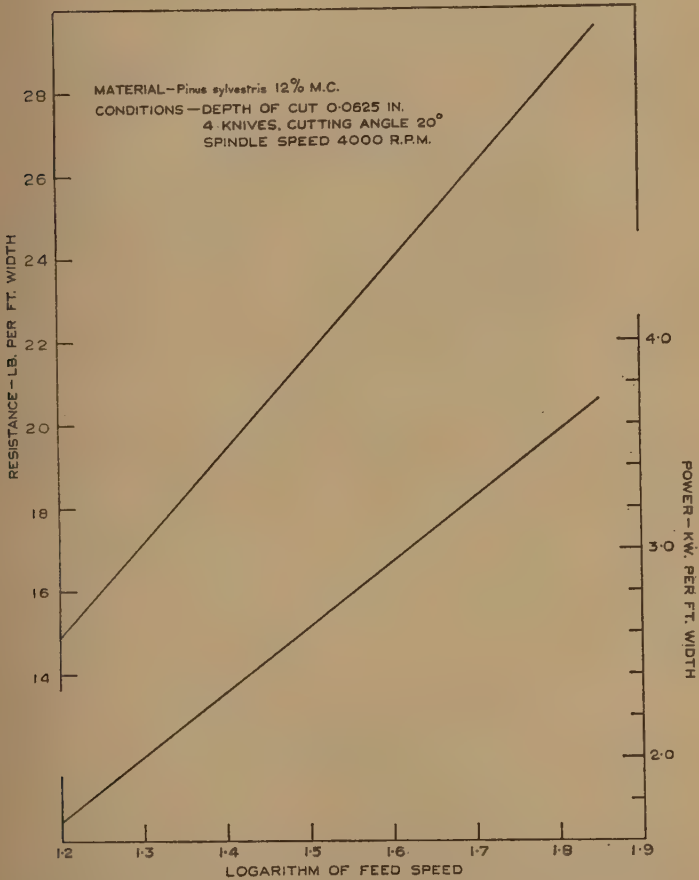


FIG. 13. *Relation of Feed Speed to Power and Resistance to Cutting*

between the timber and the machine table, before and after cutting, and the total resistance to feeding. The latter is composed of the frictional resistance mentioned above plus the mean effective resistance produced by two pulsating forces, *i.e.* the horizontal component of the force exerted by each cutter while it is in the

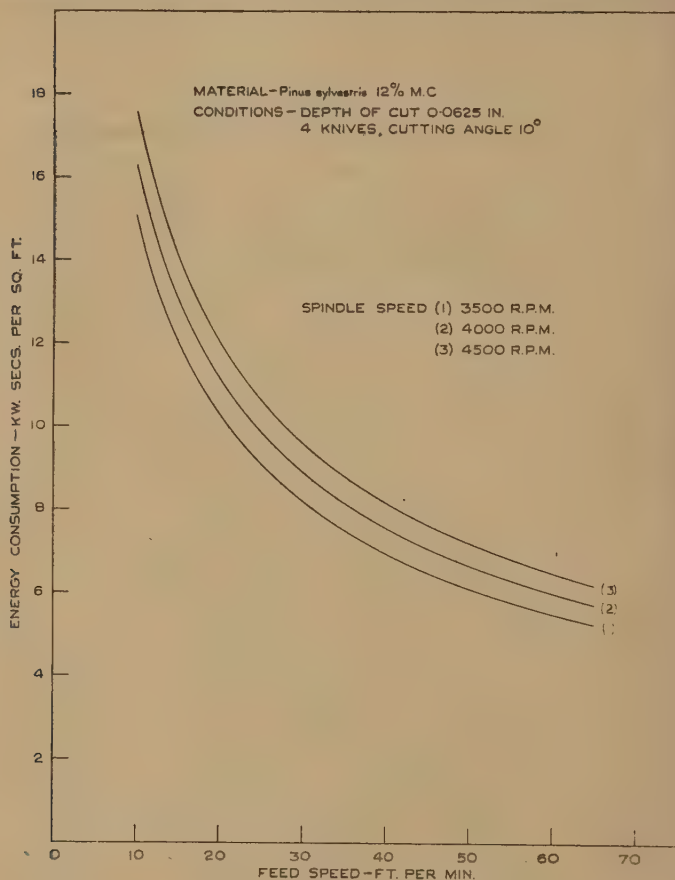


FIG. 14. *Effect of Spindle Speed on Energy Consumption*

wood and an additional frictional resistance due to the vertical component of this force. The energy consumption of the motor driving the cutterblock was measured by means of special apparatus incorporating a rotating watt-hour meter, an electro-magnetically operated stop clock and an automatic triple switch. The driving

losses to the cutterblock were measured for every test, and from the total energy consumed under load, the amount absorbed in cutting was obtained. The investigation was carried out on three species of timber, imported Baltic redwood, home-grown beech and oak, all seasoned to 12 per cent moisture content. For each species a series of testpieces of composite form was used, to obtain a wide range of sampling and to neutralise, so far as possible, the effect due to change in grain orientation relative to the plane of cutting. Some 600 tests were made at different spindle speeds, cutting angles and feed speeds. Special precautions were taken to ensure consistent results throughout the experiments. They included precision setting of the cutters and machine tables by micrometer dial-gauge, to maintain a uniform depth of cut, and measurement of the effect of any dulling that occurred during a series of tests. The spindle speed was measured for each test, to find the decrease that occurred due to the load on the cutterblock. The general conclusions drawn from certain preliminary tests carried out in 1937 have been confirmed by the results of this investigation. The effect of increasing the feed speed is to increase the power required in cutting and the resistance to feeding in proportion to the logarithm of the feed speed (Fig. 13). From the point of view of energy consumption per unit length or area of material planed, the relation to feed speed takes the form of $E = K \cdot f^{-n}$, where E is the energy as above, K is a constant partly dependent on the spindle speed, f is the feed speed and the index n (> 1) involves a function of the cutting angle. The curves in Fig. 14 show this variation in energy absorbed per unit area with rate of feeding at different spindle speeds. It will be noted that, particularly over the lower range of feed speeds, there is considerable saving in the energy required for a given run of timber as the rate of feeding is increased. In practice both electrical and labour costs of production will be lowered as the feed speed is raised. The controlling factor will be the quality of finish required, for the cut surface becomes less smooth and the cutter marks wider and deeper, with faster feeding. Additional energy will be needed if the spindle speed or the number of cutters is increased, to obtain improvement in the finish.

It is now well known that the cutting angle must be reduced to eliminate tearing when timber having interlocked, wavy or other form of cross-grain is machined. Reduction of cutting angle at given values of spindle and feed speeds increases the energy absorbed in cutting and the resistance to feeding. The advantage of a good finish and economy in subsequent operations, such as sanding and polishing, should, however, be set against the additional cost of power. For practical purposes, it can be said that under normal working conditions, a reduction of the angle from 30° to 20° will involve an increase in power consumption of the order of 25 per cent, and of 100 per cent in the case of a reduction from 30° to 10° (Fig. 15). The actual values vary with the species of timber,

seasoning condition, feed and spindle-speeds and other factors. It is of interest to note that other experiments showed that the use of skewed cutters, even with the cutting edges set at an angle of 30° to the axis of rotation, was only partly effective in obviating

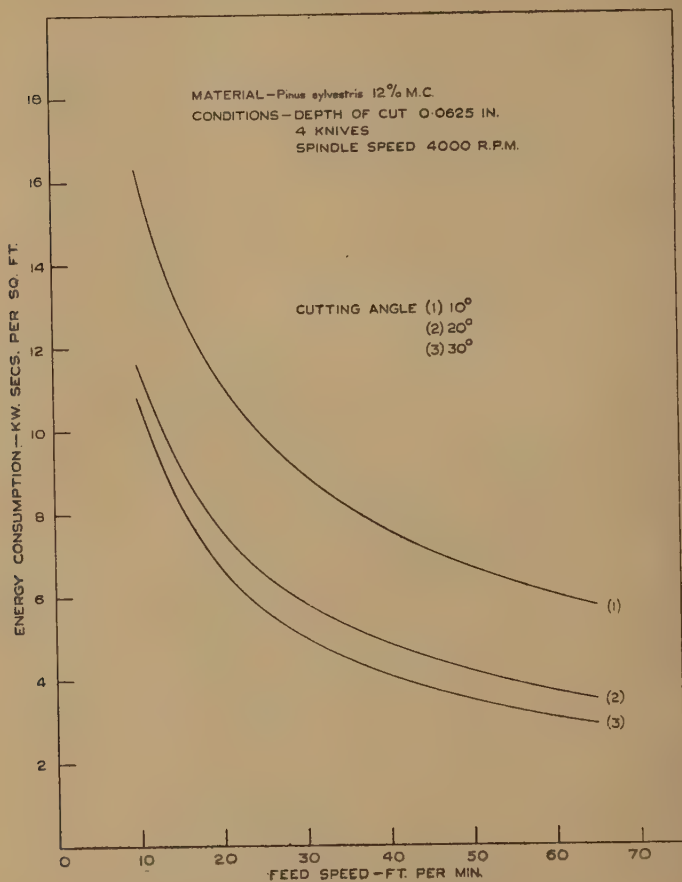


FIG 15. *Effect of Cutting Angle on Energy Consumption*

tearing when cross-grain was encountered in planing. It tended to improve the finish and facilitate the cutting action when the timber was not refractory as regards its grain, but in other cases the cutting angle still needed to be less than standard to provide the best results.

(b) *Test Work*

The working qualities of fifteen species of overseas and home-grown timbers were tested during the year. The behaviour of each species under standard working conditions was determined and the results compared with those given by various well known timbers. In certain cases, modifications to the tools, speeds, etc., were needed to obtain improved finish or ease of working. The correct tooth shape and spacing in sawing and the best cutting angle in planing were found for each timber. The effect of different steaming treatments on the working qualities of European oak, beech and elm was studied in collaboration with the Seasoning Section. The results of the tests showed that oak, particularly on cuts tangential to the growth rings, required more power and was harder to feed after steaming, the resistance to cutting increasing with the length of treatment. Steaming appeared to have little significant effect on the ease of working of beech and elm but improved the machine finish of the beech. The grain of elm showed a tendency to rise after treatment, whereas the finish of the oak showed little variation throughout the test.

An investigation was made concerning static and sliding friction between wood and various materials. The special surface-testing machine was used for certain sliding tests on worn and unused paving blocks, wet and dry, and on untreated wood having different rates of growth. Rubber, fabric, leather and wood were used in conjunction with these surfaces. Apparatus was constructed for somewhat similar experiments relating to static friction. A series of tests was also made on the experimental planer, to determine the effect of different speeds, number of cuttermarks, etc., on the frictional resistance to movement between the machine table and the timbers used in the special planing investigation.

(c) *Sawing and Saw Design*

The sawing of refractory timbers and the design of saws suitable for this purpose have received further attention. Full research on this subject is planned for 1939. In connexion with problems in sawing, mathematical study has been made of the stresses acting in bandsaws due to centrifugal tension, bending the band round the wheels, applied tension and resistance to cutting. Similarly, information has been acquired concerning the stresses acting in circular saws due to centrifugal force, thrust on the teeth and other factors.

(d) *New Apparatus*

New apparatus designed and constructed has included a precision cutter-setting device incorporating a micrometer dial gauge; a working model illustrating the variation in the forces exerted on the wood by a planer knife during the cut and in relation to the cutting angle; an inspection cabinet employing a parallel beam of light at a large angle of incidence to produce shadow effect and so exaggerate defects in machined and other surfaces.

Fire-Resistance of Timber

Tests have been carried out on the natural fire-resistant properties of different species of timber according to the standard methods, developed at the Laboratory, of testing inflammability, resistance to flame penetration and rate of burning. Over 70 different species have been tested, and of these the ones which show outstanding fire-resistant properties are:—

Greenheart	..	..	<i>Ocotea rodioei</i>
Gurjun	..	..	<i>Dipterocarpus</i> spp.
Jarrah	..	..	<i>Eucalyptus marginata</i>
Laurel	..	..	<i>Terminalia tomentosa</i>
Padauk	..	..	<i>Pterocarpus macrocarpus</i>
Pyinkado	..	..	<i>Xylia dolabriformis</i>
Teak	..	..	<i>Tectona grandis</i>
White Olivier	..	..	<i>Terminalia obovata</i>

A report on these tests is in course of preparation.

In addition to tests on untreated species fire-resistance tests have been carried out on a number of fire-resisting solutions and coatings.

Theory of the Action of Fire-proofing Compounds

Previous work has indicated that the major action of a fire-retardant chemical is its influence on the decomposition of wood when heated, resulting in an increase in the formation of charcoal at the expense of the yield of inflammable gaseous products, and has shown that effective chemicals are those which under the influence of heat dissociate to yield an acid radicle⁽¹⁾. If this action is one of dehydration as has been suggested, then the gaseous products from the carbonization of treated wood should contain less combustible organic matter, such as tars, and more water than those from untreated wood. Further work has been carried out on the estimation of the products of carbonization in order to verify this, and the following figures based on Sitka spruce and ammonium chloride are quoted for purpose of illustration.

Products Resulting from Heating at 450° C.

	Untreated wood	Wood treated with 20 per cent NH ₄ Cl
Charcoal	26	48
Condensable organic vapours, tar, etc.	33	9
Water	19	35
Uncondensed gases (by difference)	22	8
Total	100	100

The results obtained confirm that fire-retardant salts act in the manner suggested by the earlier experiments, and that the action may be described as one of dehydration. Thus a fire-retardant chemical not only decreases the amount of inflammable material evolved but at the same time results in an increase of water vapour, which by diluting the combustible gases retards or prevents flaming.

(1) RICHARDSON, N. A. A New Aspect of the Action of Timber Fire-proofing Compounds. *J. Soc. chem. Ind., Lond.*, 1937, **56**, 202T-205T.

Testing of Preservatives

(a) *Field Tests.* Periodic inspections of the large number of samples undergoing test at the various sites have been carried out. Inspections of the telegraph poles, fence posts and mine timbers undergoing service tests have also been made.

(b) *Laboratory Tests.* A series of laboratory tests has been made to determine the toxic limits of mercuric chloride, potassium bichromate and mixtures of these two salts in various proportions. Some tests have been made on the resistance to decay of samples which had been exposed to severe leaching after impregnation with water-soluble salts that are supposed to become fixed in the wood after impregnation.

At the request of manufacturers, a further number of toxicity tests have been made on various proprietary wood preservatives.

Assistance has been given to a committee of the British Standards Institution which is attempting to set up a standard method for testing the toxicity to fungi of materials used for the preservation of wood. Several meetings were attended at which the criticisms of the draft specification were discussed. It is hoped that the method will shortly be adopted as a British standard.

(c) *Laboratory Tests on Leaching.* A standard laboratory method for measuring the relative resistance of wood-preservatives to leaching from treated wood has been evolved, and a number of tests have been carried out, particularly on preservative mixtures containing alkali dichromates. The results indicate that in many cases the presence of potassium or sodium dichromate increases considerably the resistance to leaching of toxic preservatives of the water-borne type. A description of the tests and results obtained has been prepared for publication.

A New Preservative Mixture

As a result of the above-mentioned tests on leaching, a new wood-preservative mixture* has been evolved based on mercuric

* Subject of British Patent Application 3554/38 (Bryan, J. and Richardson, N. A.), controlled by the Department of Scientific and Industrial Research.

chloride as the toxic constituent. Mercuric chloride has been known as a wood preservative for over a century and is, in fact, more toxic to wood-destroying fungi than any other inorganic compound commonly used for preserving wood. Owing to the fact that it has a corrosive effect on metals, treatment must be carried out in wooden containers by steeping, a process which limits the depth of impregnation obtainable within a reasonable time. In addition, like all wood preservatives of the water-soluble inorganic salt type, mercuric chloride has a tendency to be leached from impregnated wood exposed to water or external conditions, although it possesses this disadvantage to a less degree than most other preservatives of the single salt type. This leaching not only reduces the preservative effect of the chemical but admits the possibility of poison hazard due to contamination of materials adjacent to treated wood. In the proposed new mixture these disadvantages are largely overcome whilst the unique wood-preserving properties of mercuric chloride are retained. By adding potassium dichromate to mercuric chloride solution it was found that the mercury was fixed in the wood to an extent exceeding that of other chemicals tested, and in fact under severe test conditions less than 5 per cent of the mercury was leached out of the treated wood. It was also found that, by adding to the mixture certain reducing salts such as sodium sulphite and sodium nitrite, the corrosion of iron and steel was kept within the limits normally experienced with the usual type of water-soluble preservatives, so that the solution could be used in ordinary steel treating equipment. Copper and brass are, however, attacked. Further leaching tests on this mixture showed that the mercuric chloride remained fixed in the wood to a very high degree, and subsequent tests revealed that its toxicity was in no way impaired by the presence of the other constituents. The high toxicity of mercuric chloride and the high degree of fixation permit of the use in practice of low concentrations, which enable the cost of the solution to compare favourably with that of other wood-preserving solutions. There is reason to believe that mercuric chloride is toxic to both termites and marine borers. It would appear, therefore, that owing to the high degree of fixation of the salt the mixture might prove eminently suitable for the protection of timber against these destructive agencies. It must be emphasized, however, that as in the case of all wood preservatives, only limited protection is afforded by brush or other surface treatment, and to obtain permanent protection the timber should be impregnated either under pressure or by the open tank hot and cold process.

The preservative properties of mercuric chloride are fairly well known but so far as the special properties of the mixture are concerned it must be realized that the information available is based on laboratory tests, and it is desirable that these should be confirmed by actual field tests. Such tests have already been commenced.

Lyctus Powder-post Beetles

(a) Trade Action

A feature of the year's work on *Lyctus* was the renewed interest expressed by hardwood timber merchants in the occurrence and means of control of this insect in imported timber. At the request of a section of the hardwood trade an account of the present position of the *Lyctus* problem in this country was given in February, 1938, after which a committee of certain members of the trade was formed to inquire into the subject, and the co-operation of the Laboratory invited in its deliberations. The committee's report gave an opportunity of reviewing the problem afresh, and of bringing before the section of the trade concerned methods of *Lyctus* control at present considered applicable in commercial practice. This step is important in relation to the Laboratory's work on *Lyctus* control and also to experiments in the United States of America, where methods of treating timber before export to prevent infestation by *Lyctus* are being investigated.

(b) Control

(1) Methods of Starch Depletion

The principal work on *Lyctus* control during the year has been concerned with investigations on methods of reducing the starch content of timber, thereby rendering it unsuitable for the development of the larvae. In the course of this work, co-operation has been maintained with Dr. F. Y. Henderson of the Imperial College of Science and Technology, London, who is working upon the relation between rate of starch depletion and respiration. Numerous samples cut from experimental ash disks have been exposed to *Lyctus* infestation.

The work upon the four methods of starch depletion described in the Annual Report for 1937 has been continued, and accounts of the various experiments are being prepared for publication as the results become available. As an introduction to this series of papers, a general account of the occurrence of starch in timber has been published⁽¹⁾. In it the available information on the structure, composition and physical properties of starch is summarized. The differences in properties known to exist between the starches of different botanical species, as well as differences in the associated enzyme systems, call for caution in applying to one species of timber a depletion treatment known to be successful with another. The paper includes a survey of the various methods of estimating starch in wood and a description of a standard visual method now adopted in research at this Laboratory. A clean-cut radial longitudinal surface is treated with 0.5 per cent iodine in potassium iodide solution and the amount of starch in each $\frac{1}{10}$ inch of wood, working from the outside of the tree inwards, is estimated visually

as falling into one of an arbitrary series of grades. Consideration has also been given to the part played by starch in physiological processes in the standing tree in so far as these bear on the problems involved in practical methods of starch depletion.

(1) PHILLIPS, E. W. J. The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. I. Starch, with Special Reference to its Occurrence in Timber. *Forestry*, 1938, **12**, 15-29.

(i) *Girdling*

The results of the preliminary experiment on girdling standing oaks, carried out during 1935-37 at Robertsbridge, Sussex, have now been published⁽¹⁾. In all four treated trees, two of which were felled after 5 months and two after 17 months, the sapwood below the upper girdle was found to be free from starch and was proved to be immune from *Lyctus* attack.

An experiment on a larger scale was undertaken in 1937-38 near Markyatestreet, Herts, when twenty oaks were girdled. The results of this experiment have also been published⁽²⁾. At the time of felling, 9 months after girdling, depletion of starch was recorded in the sapwood below the girdle of all treated trees, but considerable variation occurred both between trees and in different parts of the same tree. Three trees still contained sufficient starch to be adjudged definitely liable to *Lyctus* attack; eight were classed as partially susceptible and nine as immune. If such variation is normal, the method is evidently too unreliable for commercial use. In order to investigate the causes of this variation, a third and final experiment has been started, with the co-operation of the Forestry Commission, upon twenty oaks in the New Forest. The trees were girdled in two groups of ten in May and July, 1938, and will be felled early in 1939. Attention is being paid to various factors which may influence the rate of starch depletion in them.

(1) PARKIN, E. A. The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. II. A Preliminary Experiment upon the Effect of Girdling Standing Oak Trees. *Forestry*, 1938, **12**, 30-37.

(2) PARKIN, E. A. The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. III. A Second Experiment upon the Girdling of Standing Oak Trees. *Forestry*, 1938, **12**, 117-124.

(ii) *Log Storage*

No experimental work has been carried out during the past year, but visits have been paid to several firms storing quantities of English oak in the round, and borings have been taken from 50 representative logs. A preliminary examination of these borings indicates that, with very few exceptions, the starch content of winter-felled logs will have fallen by the end of the following autumn to a level below that required for successful infestation by *Lyctus*.

(iii) *Water Storage*

Work on this aspect of starch depletion has shown that there exists a considerable variation in the rate of resorption of starch by different species of timber. The sapwood of a barked 6-ft. length of oak, cut from the base of a pole and about 7 in. in diameter, became starch-free after immersion in the log pond from May to October. A 5-ft. barked length of ash 14 in. in diameter became starch-free in the period May to November, but a brownish stain developed which was not of fungal origin and resembled the stain which developed during kiln treatment of ash for starch depletion. On the other hand, two 5-ft. pieces of walnut 12 in. in diameter, one barked and one unbarked, have lost very little of their starch during immersion from January to December. It would therefore appear that during storage in water walnut does not lose its starch so rapidly as other species.

Of special interest in connection with immersion in water as a means of bringing about starch depletion was the examination of borings from a few barked logs of oak, elm and ash which had been stored in sea water in a tidal basin. Starch was still present in appreciable quantity even after five years' immersion.

(iv) *Kiln Treatment*

Investigation of the rate of starch depletion in green ash boards during a special moist heat treatment in a kiln has been continued. During experiments in a model kiln, which resulted in considerable depletion, a certain amount of chemical staining occurred in the $\frac{1}{2}$ -in. boards used, but, when treatment of a load of 1-in. ash boards in a commercial-type kiln was attempted, this staining was very marked and spoilt the appearance of the timber. Unless a method of avoiding such staining can be devised, this treatment for starch depletion must be regarded as unsuitable for ash. The method has not yet been tested with other timbers.

(2) *Laboratory Tests with Wood Preservatives for the Prevention of Lyctus Attack*

In the course of this work a neutral tar oil and a low-boiling creosote oil, supplied by Long Ashton Research Station, and also a proprietary preservative of the creosote type, tested during the year, prevented *Lyctus* attack when applied to seasoned oak sapwood by a 5 minutes' immersion treatment. In these tests an interval of approximately 2 weeks elapsed between treatment of the samples and their exposure to *Lyctus* attack.

In the report for 1937 it was recorded that a further series of tests with a 5 per cent aqueous solution of potassium chromate had been started, using a wider range of absorptions than in work previously carried out. Samples of oak sapwood were immersed

for periods varying from 5 minutes to 24 hours and exposed to *Lyctus* attack approximately one week later. None of the treatments proved effective.

An analysis of these and similar results obtained with other water-soluble salts suggested that their failure to prevent attack when applied by an immersion treatment was closely bound up with the poor penetration obtained. Tests were undertaken to determine whether increased penetration of oak sapwood could be obtained by a type of treatment which might be used commercially and without resorting to pressure impregnation processes. In the course of this work it was found that the addition of a wetting agent to the preservative solution did not improve the penetration, which, however, was appreciably increased by subjecting the wood to a preliminary heat treatment at 130° F. maintained for half an hour before immersion in the preservative. The effect of this increase and its value for preventing *Lyctus* attack are now being investigated, using aqueous solutions of preservative which, when applied under pressure, have been recommended as effective.

The Death-Watch Beetle (Xestobium rufovillosum)

(a) *Biological Studies*

The biological studies of the death-watch beetle are nearing completion, and a second paper⁽¹⁾ dealing with the results of this work has now been published.

In the course of the death-watch beetle investigations various methods of rearing the larvae so that they could be kept under observation during their growth and development have been tried. It was found possible to rear the larvae in thin sections of decayed oak sapwood held between glass plates and kept at suitable conditions of temperature and humidity. Such living material and preserved specimens of known age and history made possible a detailed study of the number of larval instars, which was undertaken during the past year. This work has now been completed and a report prepared for publication.

The experimental work carried out on the death-watch beetle during 1938 has consisted mainly of the continuation of existing experiments upon the conditions determining the susceptibility of timber to attack, from which results had not previously been obtained. Amongst these, one of the most important concerns the relation between the rate of development of the beetle and the type and extent of fungal decay in timber. The following tables summarize the most recent results of this work and show how markedly the rate of development of the insect in timber at a given temperature and moisture content is affected by differences in the extent to which it has been decayed by fungi.

- (i) Oak Sapwood decayed by *Phellinus cryptarum* (white rot)
(22° C. and 18-20 per cent moisture content)

Loss in weight of samples due to fungus, before exposure to insect. (Per cent)	Duration of life-cycle in samples
75-50	12 months or slightly less.
42-36	1½-2 years.
34-26	2½-3 years.
22-16	Attack in progress but no emergence after 3½ years.
0	No attack.

- (ii) Willow decayed by *Polystictus versicolor* (white rot)
(22° C. and 18-20 per cent moisture content)

Loss in weight of samples due to fungus, before exposure to insect. (Per cent)	Duration of life-cycle in samples
49-36	15-17 months.
31-28	15 months-2 years.
24-20	1½ years-2 years.
18-10	No emergence after 2½ years. Attack in progress.
0	No attack.

Differences in extent of decay in willow appear to have less effect than in oak sapwood, and the duration of the life-cycle of the insect is in general shorter in willow than in oak. The reasons underlying these results and an explanation of the part played by decay in determining the degree of suitability of timber for infestation by the death-watch beetle are being examined by further chemical studies of the wood before and after exposure to the insect. (See (b) Chemical Studies, p. 49.) A study of the rate of development of the insect in timber decayed to varying degrees by a brown rot caused by the cellar fungus, *Coniophora cerebella*, has been started.

Attention has previously been drawn to the need for a high moisture content in timber for the rapid development of the death-watch beetle and, conversely, the value of low moisture conditions for the prevention of attack. Additional results of experiments on this subject have become available during the year and, summarized below, provide clear evidence of the part played by moisture in rendering severely decayed wood suitable for attack.

(iii) Oak Sapwood severely decayed by *Phellinus cryptarum* (23° C.)

Moisture content of decayed wood. (Per cent)	Duration of life-cycle
8	Attack died out.
10	Not completed after 3½ years.
13-14.5	2 years 5 months.
16-18	15-16 months.

These results have been amplified by a further experiment to determine the effect of varying the moisture content of the wood in which larvae were boring. It was found that a rise or fall in moisture content caused a corresponding acceleration or retardation of their rate of development, thereby affecting the length of life-cycle of the insect.

The marked effect of temperature on the duration of the life-cycle has been noted in earlier annual reports, but is well illustrated by the following experiment from which the complete results became available during 1938.

(iv) Sapwood severely decayed by *Phellinus cryptarum* exposed to death-watch beetle attack.

(A) At 22° C. and moisture content 18-20 per cent.
Duration of life-cycle = 17 months.

(B) Out-of-doors, protected from sun and rain. Average moisture content 18 per cent.
Duration of life-cycle = 3 years.

The immediate result of practical importance arising from these studies of the factors governing the rate of development of the death-watch beetle is an indication of the conditions most favourable for attack and therefore to be avoided during repairs to buildings already infested and in the construction of new buildings. In general, it can be concluded that warm, moist conditions favouring the development of decay, as in an ill-ventilated roof, are far more suitable for attack by the death-watch beetle than the dry, cool conditions prevailing in a well-ventilated and sound structure.

With the acquisition of new knowledge on the biology and food requirements of the death-watch beetle, it has been possible to devote some attention to the study of insecticides and preservatives for its control. A start has been made by determining the relative value, for the prevention of egg-laying and hatching, of three of the liquids most commonly used for the treatment of attacked timber.

All three prevented hatching of the eggs but two did not prevent egg-laying. The duration of efficacy of the substances for preventing infestation will be the subject of further experiment.

(1) FISHER, R. C. Studies of the Biology of the Death-Watch Beetle, *Xestobium rufovillosum* De G. II. The Habits of the Adult, with Special Reference to the Factors Affecting Oviposition. *Ann. appl. Biol.*, 1938, 25, 155-180.

(b) Chemical Studies

In continuation of previous work, detailed analyses have now been obtained to show the effect of the fungus *Phellinus cryptarum* on the chemical composition of samples of oak sapwood which have lost up to 75 per cent of their original weight as a result of decay. The fungus is consistent in its effects throughout all stages of decay, in that the major wood components are decomposed in roughly the same proportions in which they occur in sound wood. It has been shown above that the larvae of the death-watch beetle bore more rapidly, cause more destruction and reach maturity earlier in badly decayed wood than they do in moderately decayed wood, but it has now been found that as fungal decay becomes more advanced they actually digest a much smaller proportion of the wood which they comminute. It is strongly suggested, therefore, that the function of the fungus in this type of biological succession is not so much predigestion, by breaking down of the wood components to simpler substances capable of ready assimilation by the larvae, as the weakening of the structure by chemical decomposition so that the larvae encounter less resistance to boring. From this it follows that control of this insect can best be attained by methods involving the withholding in susceptible woods of the essential conditions of life, from both fungi and the insect, by the use of insecticides or other agencies. The question as to whether the fungus mycelium itself is utilised by the larvae as food has not been overlooked. The indications are that the larvae reject, or fail to digest a larger relative proportion of mycelium than of the decayed wood, and this obtains despite the observation that the mycelium in the various samples of decayed wood probably contained sufficient nitrogen to satisfy the requirements in respect of that element of as many larvae as the samples could support.

Pinhole Borers

During the past few years there has been an increase in the number of inquiries received concerning damage to English oak by the pinhole borer *Platypus cylindrus*. Opportunity was therefore taken of collecting information on the occurrence and importance of this beetle when, during the year, visits were paid to the yards of firms holding large stocks of English oak logs for the purpose of obtaining borings for starch determination. (See page 44.) From this information, it is evident that, in southern England, infestation

by *Platypus cylindrus* has grown to serious proportions and that timber merchants are concerned at the extent of damage caused by this beetle, which can penetrate the heartwood as well as the sapwood of oak logs and green timber of large dimensions stacked for air-seasoning. During July and August, infestation was found to be taking place both in the woods and in timber yards.

Time cannot at present be devoted to a detailed study of this insect and methods of its control, but, as opportunity affords, further information is being collected upon its distribution, and a number of lengths cut from infested oak logs are being kept under observation at the Laboratory. Disks from these are being examined at intervals so that some general data may be obtained upon the life-cycle and habits of the beetle.

The House Longhorn Beetle

No further instances of the occurrence of the house longhorn beetle, *Hylotrupes bajulus*, have come to the notice of the Laboratory during the past year. In connexion with the visit to Germany and Denmark referred to in the last report, an account⁽¹⁾ has been published of information collected on insurance in these countries against risk of infestation of buildings by *Hylotrupes* or by dry rot.

⁽¹⁾ FISHER, R. C. Insurance of Buildings against Insect or Dry Rot Attack. *Post Mag. Insur. Monit.*, 1938, **99**, 845-847.

Physiology of Digestion in Wood-boring Larvae

The digestive enzymes of four species of wood-boring larvae of the families Bostrychidae, Cerambycidae and Platypodidae have been investigated during the year, and the total for this investigation is thereby brought to 12 species representing 6 families.

The Use of Toxic Gases for destroying Insects in Wood

In continuation of the work on fumigation as a means of sterilizing insect-infested timber and furniture⁽¹⁾, a further experiment has been carried out in a commercial fumigation chamber, using hydrogen cyanide, with 1-in. thick samples of ash infested by *Lyctus brunneus* and blocks of elm and beech 1-3 in. thick attacked by the furniture beetle *Ptilinus pectinicornis*. Some samples were coated with paraffin wax on the transverse surfaces in order to prevent excessive end-penetration of the gas, which might unduly influence the result in short samples. The results suggest that the more severely attacked the wood the better will be the penetration obtained, and that with an initial concentration of 28·7 mg. per litre in the chamber the amount of hydrogen cyanide entering the wood during an exposure of 4½ hours at a temperature of 70° F. is sufficient to kill most, if not all, of the larvae in infested furniture. The rate of progress of damage could therefore be greatly reduced, and a second treatment after an interval of a year should serve to eradicate infection.

The proposal to use toxic gas to destroy insects in wood raised the question of obtaining diffusion rates for the gas which could be applied to samples of different sizes instead of relying on empirical determinations. Since a knowledge of the rate of penetration of gases into wood is also of value in other problems, notably the drying and preservative treatment of wood, the co-operation of the National Physical Laboratory was sought in order to make some measurements on the rates of diffusion of hydrogen and carbon dioxide through thin boards into air and, later, measurements of the retention of hydrogen cyanide by wood were also undertaken. It was presumed that the rates for hydrogen cyanide would be intermediate between those for hydrogen and carbon dioxide.

The results of the diffusion experiments, which have been published⁽²⁾, showed considerable differences between the three species studied—beech, oak and Scots pine—and between the two directions of flow—radial and tangential. They proved, however, to be entirely consistent with known facts about the botanical structure of the wood, certain portions of which function in the living tree as conductors of liquids or vapours.

The times for the attainment of toxic concentrations were calculated with the aid of a few simplifying assumptions and were found to be, for some woods at least, within reasonable limits for practical application. No great accuracy can be claimed for the figures, but they show that even neglecting the possible presence of cracks and beetle exit holes, the rate of conduction is not so low as to make the fumigation process for wood an impracticably slow one.

The experiments on retention of hydrogen cyanide have not yet been completed.

(1) *Rep. For. Prod. Res. Bd., Lond.*, 1937, **1936**, 41.

(2) BARR, G., THOROGOOD, A. L., and VAN REST, E. D. The Diffusion and Effusion of some Gases through Wood. *J. Soc. chem. Ind., Lond.*, 1938, **57**, 339-344.

X-rays as a Means of Detecting the Presence of Wood-boring Insects

The experimental work in this investigation, carried out in co-operation with Messrs. Ilford, Ltd., was completed during the year. A long series of radiographs of insect-infested timber of different thicknesses has been examined and compared with the numbers of insects and their distribution as revealed by subsequent detailed examination of the samples radiographed. A joint report is in course of preparation in which it is shown that although the general condition of a sample of wood with reference to the presence of insect tunnels can readily be determined by X-rays, their use for the detection of wood-boring insects, living or dead, is likely to be restricted to timber of small dimensions, *e.g.* plywood. The method has been shown to be impracticable for detecting the death-watch beetle and its larvae in structural timbers.

Decay in Wood

A description of the nature of decay and of the organisms which cause it, written in simple language for the benefit of students and practical men, has been published as a Forest Products Research Record⁽¹⁾. Methods of handling timber so as to prevent its deterioration during seasoning and storage are also described.

The second edition of the bulletin on dry rot having become exhausted, the opportunity has been taken to revise it thoroughly. With the assistance of the Building Research Station the section dealing with the precautions to be taken to prevent the penetration of damp and consequent development of rot in buildings has been completely re-written, and the third edition has now been published⁽²⁾. Attention has been drawn to the necessity for protecting parapet walls against damp penetration, as flat roofs with this form of construction have recently become increasingly popular.

⁽¹⁾ FINDLAY, W. P. K. Decay of Timber and its Prevention. *For. Prod. Res. Rec.*, 1938, No. 27.

⁽²⁾ CARTWRIGHT, K. St. G., and FINDLAY, W. P. K. Dry Rot in Wood. *Bull. For. Prod. Res., Lond.*, 1938, No. 1 (3rd Edition).

Decay in Hardwoods other than Oak

Considerable progress has been made with the accumulation of data for a small but comprehensive handbook describing the principal decays of hardwoods, other than oak, which are commonly used in this country. This publication will follow the lines of the bulletin on the decays of softwoods, which was published recently⁽¹⁾.

⁽¹⁾ CARTWRIGHT, K. St. G., and FINDLAY, W. P. K. *Principal Decays of Softwoods used in Great Britain*. H.M.S.O., London, 1938.

Physiological Studies of Wood-destroying Fungi

A further series of experiments has been carried out to determine the succession of changes in the hydrogen-ion concentration of a nutritive medium, such as dilute malt extract, in which a wood-destroying fungus is growing. It appears that those fungi which bring about a brown rot, *i.e.* those which attack cellulose and carbohydrates only, cause such a medium to become very acid and to remain so, whereas the fungi which produce a white rot cause an initial development of acidity which disappears after some weeks, the *pH* of the medium then going back to about its original figure. The reason for this difference is being sought. It is planned also to investigate the amount and nature of the organic acids produced by fungi growing in wood.

The results of the experiments, referred to in the last report, on the effect of the presence of rusting iron on the rate of decomposition of wood by fungi, have shown that the effect of the rust is to reduce the amount of fungal decay, the presence of a small amount of soluble iron salts evidently having a toxic effect on the fungi.

Fungus Association in Siricidae

A note summarizing the results of further work on the fungi associated with *Sirex* wood-wasps has been published⁽¹⁾. It has been shown that the fungus associated with *Sirex gigas* is *Stereum sanguinolentum*, and that the fungus in *S. cyaneus* is very similar in culture to *S. sanguinolentum*, of which it is possibly a form. The fungal hyphae were found to be present in glands at the base of the ovipositor in female pupae in an advanced stage of development. It was shown that the fungus is introduced into the wood during oviposition. Only slow development of the fungus can take place at a moisture content favourable for the development of the larva. Under more moist conditions vigorous fungus growth, which may have results fatal to the larvae, occurs.

⁽¹⁾ CARTWRIGHT, K. St. G. A Further Note on Fungus Association in the Siricidae. *Ann. appl. Biol.*, 1938, **25**, 430-432.

Laboratory Tests of Natural Durability

Further laboratory tests have been made to determine the resistance to decay of additional species of home-grown and Empire timbers. A paper has been published describing the methods used and summarizing the results of all the tests on hardwoods which have been carried out up to date⁽¹⁾. The results of the tests on softwoods have been included in the booklet on the decays of softwoods.

In view of the divergent opinions held in the trade about the resistance to rot of Douglas fir, it was decided to carry out a comprehensive experiment on the resistance to fungal decay of a series of assorted samples of Douglas fir collected in various districts of British Columbia and forwarded to the Laboratory through the kindness of the Forest Products Laboratories of Canada. It is proposed, for comparative purposes, to carry out similar tests on a series of samples of Baltic redwood obtained from various northern countries.

⁽¹⁾ FINDLAY, W. P. K. The Natural Resistance to Decay of some Empire Timbers. *Emp. For. J.*, 1938, **17**, 249-259.

Prevention of Mould on Paint

The resistance to the attack of mould of further samples of white lead paint containing various antiseptic substances has been examined, using the method described in the Annual Report for 1936. No substance has been discovered which is wholly effective, but several have been found greatly to increase the resistance of the paint to micro-organisms. Some antiseptics, particularly if they have an alkaline reaction, may prevent the growth of mould yet have a bad effect on the other qualities of the paint.

Staining Fungi

It is popularly believed that wood affected by blue stain is more liable to dry rot than unstained wood. A series of carefully controlled tests has therefore been made to compare the resistance of clean and stained pine sapwood to certain fungi which cause dry rot. It was found that though the stained wood was slightly more readily attacked than the clean, the difference in liability to rot was not likely to be of practical importance. Blue-stained wood absorbed liquid more rapidly than wood which was free from stain, when comparable samples were submerged under water, and it is suggested that the more rapid decay of the stained wood may be correlated with its greater porosity to liquids and gases. A paper summarizing this work has been published⁽¹⁾.

In the kiln-drying of oak trouble is sometimes experienced from a yellow mould growing over the boards, especially in the sapwood, and staining them a bright yellow colour. This fungus, which is one of the *Penicillium divaricatum* group, has received various names, e.g. *Paecilomyces varioti* and *Eidamia catenulata*. Since it is able to grow at temperatures up to 44° C. it finds ideal conditions for its development in the early stages of the kiln-drying of oak planks. It has been found that the development of the mould can be checked by dipping the planks in a solution of one of the proprietary anti-stain substances of the chlorinated phenol type, but that the growth of the mould was not entirely inhibited when the planks were dipped in solutions containing up to 1.25 per cent of the antiseptic. It is proposed to make some further tests to determine what concentration of the antiseptic would entirely prevent the development of the mould.

The superficial growth of mould which may develop in a kiln on planks that have not been dipped may be checked by spraying the pile of timber with a solution of formaldehyde, but this is an unpleasant operation, involving the use of a respirator, and it does not prevent internal staining. Therefore it is much better to dip the planks in the antiseptic solution immediately after they have been sawn.

- (1) FINDLAY, W. P. K. Effect of Sap Stain on the Properties of Timber. II. Effect of Sap Stain on the Decay-resistance of Pine Sapwood. *Forestry*, 1939, **13**, 59-67.

Resistance of Adhesives to Decomposition

Certain preliminary tests had shown that there was a great difference in resistance to dampness and to bacterial decomposition between the various types of adhesive used in the manufacture of plywood. It was, therefore, decided to make a series of quantitative tests to compare the resistance to dampness and to microbial decomposition of plywood glued with various adhesives, by measuring the loss in adhesive strength of samples exposed for various periods

to conditions favourable for the growth of micro-organisms. Samples of birch plywood glued with adhesives selected from the four main types commonly used in practice, namely, animal glue (Scotch type), casein glue, blood albumin glue and a synthetic resin glue of the film type, were obtained. A series of samples of each type was exposed at a constant temperature of 35° C. to very moist conditions favourable for the development of micro-organisms, and batches were tested after various periods of exposure. A duplicate series of samples which had been exposed to the same conditions but which had been kept sterile by the addition of an antiseptic was also tested. It was found that both sets of samples having an animal glue as the adhesive failed from the effect of moisture alone after a few hours. The casein glue joints became progressively weaker, but there was no difference between the infected samples and the sterilized ones, indicating that the loss in strength was due primarily to the effect of the moisture. When blood albumin was used as the adhesive, however, the infected specimens rapidly lost adhesive strength, which fell to less than 50 per cent of its original value after 5 days' exposure, whereas the sterile specimens under the same conditions showed no decrease in strength, thus indicating that this adhesive is very susceptible to attack by micro-organisms.

No difference in strength between the sterile and the non-sterile specimens was observed in the samples of plywood in which a synthetic resin glue was used, which may thus be considered as immune from attack by micro-organisms. There was, however, in both these series of samples a slight reduction in strength which may be ascribed to the warm, moist conditions.

Though the adhesives chosen were of the main types commercially used, it is realized that certain proprietary adhesives of the same types may have substances incorporated in them which may alter their behaviour under the conditions of this test.

A paper describing these experiments and other results obtained has been prepared for publication⁽¹⁾.

Suggestions have been made with a view to incorporating a simple standard test for resistance to microbial decomposition in a British Standard specification.

⁽¹⁾ ERNEST, E. C. M. and PETTIFOR, C. B. Adhesion in Plywood. The Effect of Warm, Moist Conditions. *Wood*, 1939, **4**, 65-66.

Bleaching of Wood

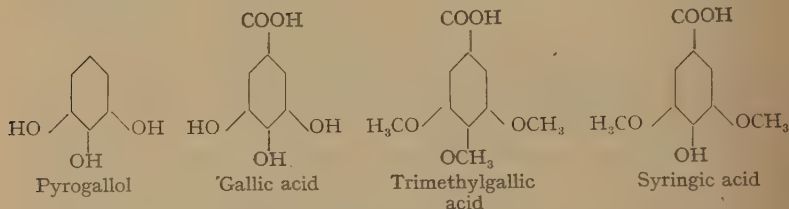
Investigation of the bleaching action of alkaline hydrogen peroxide on wood has been continued. The following order of events in the bleaching process has been established :—(1) darkening of the wood followed by the leaching out of a dark-coloured extract, (2) simultaneous bleaching of the extract and wood with evolution of gas. Certain non-carbohydrate components of wood are leached out and decomposed by oxidation into products which, either alone or in combination with alkali, are soluble in water.

It has been found that alternate pre-treatments with alkaline hydrogen peroxide and chlorine gas constitute an efficient delignification process for wood in sawdust form, but the present cost of hydrogen peroxide would render the process too expensive for application on a large scale. The publication of a short paper on the bleaching action of hydrogen peroxide on wood⁽¹⁾ gave rise to a considerable amount of interest as evinced by the number of inquiries on this subject received at the Laboratory.

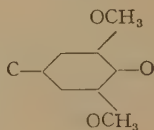
⁽¹⁾ CAMPBELL, W. G. and SWANN, G. The Bleaching Action of Alkaline Hydrogen Peroxide on Wood. *Biochem. J.*, 1938, **32**, 702-707.

The Chlorine : Sodium Sulphite Colour Reaction of Woody Tissues

Although it has long been known that chlorination followed by the addition of sodium sulphite gives with hardwoods a characteristic magenta coloration and with softwoods a brown coloration, neither the mechanism nor the significance of the colour reaction has hitherto been explained. In work upon which a preliminary paper was published in 1937⁽¹⁾, and a second in the current year⁽²⁾, it has been established that the magenta coloration given by hardwoods and hardwood lignin is also given by the following derivatives of pyrogallol :—



So long as at least one OH group in a pyrogallol derivative is unsubstituted, the colour reaction can be produced by oxidizing agents other than chlorine and weak alkalis other than sodium sulphite. When on the other hand, all three OH groups are alkylated as in trimethylgallic acid, chlorination is a necessary antecedent to the production of the magenta coloration with sodium sulphite. The major reaction product is a chlorinated derivative of trimethylgallic acid, but the colour reaction is given by traces of a phenolic body which is produced by the demethylating action of chlorine on the starting material. The analogy with respect to this particular colour reaction between trimethylgallic acid and hardwood lignin led to the deduction that the latter body contains a recurring unit of formula



which is in agreement with certain recent results obtained by Freudenberg⁽³⁾, Leger and Hibbert⁽⁴⁾ and others.

⁽¹⁾ CAMPBELL, W. G., BRYANT, S. A., and SWANN, G. The Chlorine : Sodium Sulphite Colour Reaction of Woody Tissues. *Biochem. J.*, 1937, **31**, 1285-1288.

⁽²⁾ CAMPBELL, W. G., MCGOWAN, J. C., and BRYANT, S. A. The Chlorine : Sodium Sulphite Colour Reaction of Woody Tissues. II. The Bearing of the Colour Reaction on the Constitution of Hardwood Lignin. *Biochem. J.*, 1938, **32**, 2138-2141.

⁽³⁾ FREUDENBERG, K. Neues über Lignin. *Papier-fabrikant*, 1938, (Tech. Teil) **36**, 34.

⁽⁴⁾ LEGER, F., and HIBBERT, A. The Isolation of Guaicol and Pyrogallol 1, 3-Dimethyl Ether from Hardwood Waste Sulphite Liquor. *Canad. J. Res.*, 1938, **16**, 151.

The Hemicelluloses of Oak Wood

A considerable advance has been made towards the elucidation of the constitution of hemicellulose A during the year under review. It has been established that this body is composed of mixed polysaccharide chains. The essential constitutional difference between the sapwood product and the heartwood product is that the former contains anhydro-glucose residues, whilst the latter does not. The sapwood product gives a blue coloration with iodine, which is identical with that given by starch. Digestion of sapwood hemicellulose A with takadiastase under controlled conditions⁽¹⁾ for 48 hours results in the hydrolysis of the anhydro-glucose portion, and the residue has the same specific rotation (-97.5°) as heartwood hemicellulose A.

Prolonged digestion with takadiastase for periods up to 210 hours has provided a convenient method of splitting hemicellulose A from which the glucose residues have been removed into two relatively simple components, namely, the reducing sugar xylose and a water-soluble polysaccharide. On further hydrolysis with dilute mineral acid, the soluble polysaccharide yields xylose, and a monomethoxyhexuronic acid. It has been deduced that the smallest possible recurring unit in isolated heartwood hemicellulose A consists approximately of eleven anhydroxylose units and one methoxyhexuronic anhydride unit. The presence of such a unit in hemicellulose A was demonstrated in previous work⁽²⁾, but at that time it was not known that it constituted the sole recurring unit in the heartwood product as well as in the sapwood product after removal of its constituent glucose residues. The recurring unit in sapwood hemicellulose A as ordinarily isolated is composed approximately of one anhydro-glucose residue, eleven anhydroxylose residues and one methoxyhexuronic anhydride residue. The composition of oak hemicellulose B is now being determined.

⁽¹⁾ O'DWYER, M. H. The Hemicelluloses of the Wood of English Oak. III. The Fractionation of Hemicellulose A. *Biochem. J.*, 1937, **31**, 254-257.

⁽²⁾ O'DWYER, M. H. The Hemicelluloses of the Wood of English Oak. II. The Composition and Properties of Hemicellulose A, isolated from samples of Wood dried under various Conditions. *Biochem. J.*, 1934, **28**, 2116-2124.

The Starch and Related Polysaccharides of Certain Hardwoods

Interest in the above substances is being maintained from the constitutional standpoint. In this connection it has been found necessary to investigate the accuracy of the analytical method usually employed to estimate uronic anhydride groups which consists in boiling the polysaccharide with 12 per cent hydrochloric acid and determining the amount of carbon dioxide liberated. A modified form of apparatus has been evolved which gives consistent, small blanks, and with this it has been possible to show, in co-operation with Professor E. L. Hirst and Dr. G. T. Young of Bristol University⁽¹⁾, that a representative number of carbohydrates evolve carbon dioxide when boiled with hydrochloric acid. It has been concluded that no structural significance can be attached to carbon dioxide yields from starches when of the order of 0.3-0.5 per cent, but since the yields from wood starch preparations are higher than 0.5 per cent the claim that these contain uronic anhydride⁽²⁾ is not affected except in so far as the numerical value of the results is concerned.

⁽¹⁾ CAMPELL, W. G., HIRST, E. L., and YOUNG, G. T. Estimation of Uronic Anhydride Residues in Polysaccharides. *Nature*, 1938, **142**, 912-913.

⁽²⁾ CAMPELL, W. G. The Starch and Related Polysaccharides of Certain Hardwoods. *Biochem. J.*, 1935, **29**, 1068-1080.

Charcoal Manufacture in Portable Kilns

The increasing use of charcoal in various industrial processes, particularly in the manufacture of rayon, has demonstrated that this country is very largely dependent upon foreign supplies. With the object of encouraging home production, a project, outlined in 1938 and approved by the Forest Products Research Board, for investigating the manufacture of charcoal in portable steel kilns was commenced early in the year. It has been felt that the development of a home industry would not only provide employment and utilize a class of forest produce which is almost valueless for any other purpose, but would at the same time give a measure of insurance against a possible decrease in foreign supplies.

A few portable steel kilns have been in use during the last ten years or so, but it is believed that the quality of charcoal produced in them has not always been satisfactory for industrial purposes, particularly those regularly absorbing the largest quantities. Accordingly, the investigation has been directed firstly to ascertaining whether this type of kiln is capable of producing a first-class charcoal, and secondly towards the development of carbonization technique.

An experimental kiln (Fig. 16) has been designed and constructed, which, while following closely in general principles the proprietary kilns available, at the same time has sufficient flexibility in operation to permit of a wide range of experiment.



FIG. 16. *Forest Products Research Experimental Charcoal Kiln*
(Recording pyrometers can be seen on the right and left)

The results already achieved during 1938 are most encouraging. It has been conclusively demonstrated that this type of kiln can produce charcoal of the highest quality and that by following quite simple rules such kilns can be operated by comparatively unskilled labour.

The main objection to the charcoal hitherto made in portable kilns has been that it contained too high a percentage of volatile matter for many industrial uses. A method of reducing the percentage of volatiles to tolerable limits has now been evolved, and the charcoal produced by certain experimental burnings has been pronounced by a leading firm of rayon manufacturers, which has given financial support to the investigation, to be equal to the best it has had from any source.

A further development has been the achievement of positive control over the rate and uniformity of carbonization by a simple device, which makes regulation of burning practically automatic and independent of prevailing wind conditions.

Co-operation has been maintained with the above-mentioned firm through check analyses of the charcoals produced, and also with a firm engaged in manufacturing case-hardening compounds, with a view to producing the most suitable type of charcoal for incorporation in their products.

Further work has been planned for 1939. Developments will be in the direction of correlating maximum yield with low volatile content, and in studies of methods of carbonizing various timbers in different dimensions.

During the period under review, sixty-two inquiries concerning charcoal were dealt with, and advice was given as to the possibilities and methods of manufacture, and its use in industrial processes or as fuel for gas producers.

Gazogenes

Close touch has been maintained with developments in the use of wood and charcoal as alternative fuels for motor vehicles. Interest in the possibilities of producer gas derived from these fuels appears to be on the increase, particularly in the colonies and dominions where liquid fuels are often expensive and difficult to obtain.

Pruning

The pruning project—an investigation into the possibilities of improving the quality of home-grown timber by artificial pruning of the living tree—was continued as fresh material became available. The main difficulty has been in obtaining logs from trees pruned under proper conditions, and sufficiently long ago to provide material which will enable an estimate to be made of the time necessary for the healing over of pruned wounds and of the effect this is likely to have on the ultimate quality of the timber.

The examination of such fresh material has served to confirm the probability that artificial pruning carried out at an early age and in the correct manner will prove an economical means of producing clean timber.

Wood Wool

In co-operation with the National Home Grown Timber Council, billets of home-grown softwoods were examined and graded for quality to determine to what extent they were suitable for the manufacture of wood wool. A brief report was prepared and submitted to the National Home Grown Timber Council. In correlation with this laboratory examination, actual cutting tests were carried out by a wood wool manufacturer.

The Qualities and Commercial Possibilities of Home-grown Sitka Spruce

During the year reports were received from two woodworking firms on the behaviour of home-grown Sitka spruce from various localities and grown under different conditions. These reports complete the investigation into the properties of home-grown Sitka spruce, and the results have now been embodied in a final report. Although no first quality material was produced from the nine consignments dealt with in this investigation, there was considerable difference between them. Logs sent from Cockle Park, Durham, by courtesy of the Department of Agriculture, University of Durham, and others received from the Forestry Commission areas in Argyllshire yielded material which was pronounced suitable for the best class of printed boxes.

All trees dealt with in the investigation were comparatively young, and many were grown at much too fast a rate to produce good timber. The investigation has shown that, given suitable silvicultural treatment, this species will eventually produce material comparable with the better qualities grown under similar conditions in Canada and the United States.

Photography and Cinematography

The routine work in the Photographic Section has been approximately the same as in 1937, the number of negatives, prints and slides made is practically the same as last year's output, but the number of blue prints has been trebled.

Experiments with Dufay colour films have been made in the production of photomicrographs of mycological subjects and of stained wood sections.

A great deal of work was done for the Glasgow exhibition, in production of both photographs and cinematograph films.

The cinematograph section is now equipped with sound apparatus, and a sound film, 400 feet in length, dealing with the death-watch beetle has been made.

The silent films already made have been frequently used by officers for lectures, and certain technical schools have exhibited them.

Work, both photographic and cinematographic, has been carried out by the staff of this Section for other stations and research associations, and many hours have been spent by the staff at exhibitions for the purpose of projecting films.

Apart from the death-watch film, a new film on Box Testing had been made, and two dealing respectively with Dry Rot and the *Lyctus* beetle are in course of production.

To demonstrate the method used in the Laboratory for testing the toxicity of wood preservatives, a cinematographic film was taken showing simultaneously, on the one hand, the growth of the test fungus over an untreated block of wood, and on the other, the inhibiting effect of the preservative in a treated block on the growth of the fungus. The rate of growth of the fungus appeared on the screen to be very rapid, owing to the fact that the pictures had been taken at 15-minute intervals by means of a specially designed time lapse apparatus worked by a clock⁽¹⁾.

⁽¹⁾ HARRIS, P. Automatic Operation of Ciné-camera and Lighting Arrangements for Time Lapse Studies. *Nature*, 1938, **142**, 834.

Publications and Records

The number of entries in the card index of trade and vernacular names of timbers now exceeds 50,000. The value of this index for ready reference is very considerable, particularly for tracing names which are frequently referred to the Laboratory by outside inquirers.

Ten new publications were issued through H.M. Stationery Office during the year, as well as revised editions of two bulletins and seven leaflets. Particulars of these and of the various papers published in scientific and technical journals may be found in Appendix III.

The second edition of the Handbook of Home-grown Timbers, the first of which was issued at the end of 1936 and was sold out during 1938, has been prepared for publication. Data on four further species, and three appendices, have been added, the latter giving information on kiln-drying schedules, saw types suitable for the various species dealt with, and the mechanical properties of the timbers. The companion volume, A Handbook of Empire Timbers, referred to in last year's report, is also in the press. In addition to the above, thirty-four miscellaneous and progress reports have been prepared.

Once again the thanks of the Laboratory are due to various institutions and authors for valuable gifts to the Library.

III. ADVISORY WORK

Wood Structure

The number of inquiries has again been greater than in any previous year. About 50 per cent of these were concerned with the identification of timbers in the form of samples or manufactured articles. In many cases this information was required in order to obtain supplies of some particular grade of timber or to establish the identity of a timber offered under an unfamiliar trade name. This type of inquiry is often valuable as indicating the kinds of timber used for various purposes by manufacturers in this country and by foreign competitors.

Seasoning and Wood Bending

The number of inquiries received during the year in connection with seasoning and bending problems amounted to 692, representing an increase of over 30 per cent on the previous year. Over 80 per cent were from trade sources, 30 per cent of the inquiries being on the subject of the behaviour of seasoned wood in service in so far as it is influenced by moisture content fluctuations. Advice and assistance sought on drying equipment and methods amounted to a further 40 per cent of the inquiries received.

Arising out of inquiries a number of experiments were carried out by special request. These included tests to determine how the hygroscopicity of wood is affected by fire-proofing treatments, the effect of exposure to damp conditions on the subsequent tendency of veneers to lift and blister, the influence of moisture content changes on block boarding in so far as they produce corrugation of the surface due to differential movement in the core, the behaviour of wood block flooring when laid in asphalt as compared with the usual method of laying in mastic, the kiln-drying of maple shoe-last blocks, and the kiln-drying of beech brush-back blanks.

Seventeen representatives of commercial firms attended at the Laboratory between January and October for courses of instruction in kiln operation and the principles of seasoning. This system of training absorbed so much of the staff's time that it was discontinued at the end of October, and it was decided to substitute a course of one week's concentrated study.

Timber Mechanics

The number of inquiries concerning the strength of timber and allied materials continues to increase. In addition to requests for information concerning the properties of timbers, plywoods, glues, etc., a considerable volume of inquiries is received concerning special applications of such materials, methods of construction, etc. Several series of tests have been carried out by request during the year including an investigation of the strength of mine timbers

for a colonial forestry department, tests of timber for vehicle body manufacturers, tests of Sitka spruce with reference to use for aircraft construction, an investigation of the properties of plywood faced with fibre, etc.

Woodworking

The advisory work relating to the conversion of timber, manufacturing processes and allied subjects continues to grow. Inquiries concerning woodcutting are far from stereotyped; problems raised are often of a complex nature and their solution needs a synthetical treatment. The subjects on which information was required included:—causes and possible remedies for mechanical failure of saws, cutterheads, etc.; factors affecting the efficiency and finish in various machining operations; mathematical data relating to the stresses acting in saws; comparative costs of production with use of steam and electrical power; utilization of wood waste and design of plant for this purpose; modifications to cutting conditions necessary to obtain improved results in the working of a number of timbers; design of tools and machines for special purposes; specifications for saw teeth, cutting angles and speeds for particular species of timber; power requirements in various operations, and a variety of other matters.

Wood Preservation

During the year many inquiries on matters relating to wood preservative and fire-proofing treatments have been answered. These have included requests for information concerning the fire-proofing and preservation of timber for national defence purposes.

Entomology

During 1938 the number of inquiries dealt with by letter on insect damage to timber amounted to 684, an increase of 66 over the previous year's total. The insect most frequently concerned was the common furniture beetle, *Anobium punctatum*. Damage by longhorn beetles was the subject of a large proportion of the additional inquiries, amongst which some were of special interest.

In addition to inquiries by letter, 22 inspections were carried out on payment of a fee, mainly for architects and church authorities. One half of this total referred to death-watch beetle attack and the remainder to damage by other wood-boring insects.

During recent years some inquiries have been received concerning damage by *Ernobius mollis*, one of the Anobiid or furniture beetles, resulting from the use of unbarked coniferous timbers for structural or joinery work. An account ⁽¹⁾ of the damage caused by this insect and methods of prevention was published during the year.

⁽¹⁾ CANN, F. R. An Uncommon Type of Furniture Beetle Damage in Softwoods. *Builder, Lond.*, 1938, **154**, No. 4965, 654-655.

Mycology

The number of advisory inquiries dealt with by the Mycology Section again showed an increase on the preceding year. Whereas the majority of these have related, as in previous years, to the decay of timber in buildings, a considerable number have been concerned with mould and stain on timber. Staining in cargoes of hickory has been the subject of several inquiries. Another noticeable feature has been the number of inquiries concerning doté (incipient decay) in Douglas fir caused by *Trametes serialis*, which develops only under unsuitable conditions of storage.

Wood Chemistry

In recent years the timber trade has shown a tendency to make fuller use of the chemical services of the Laboratory, as the number of inquiries dealt with by this Section in the year under review was 135, compared with a mere score or so in certain previous years. The subject matter of these inquiries fell into no less than 40 separate sub-divisions. Information was sought in over 40 cases on the use of woods under special conditions, and advice was given in 57 cases involving stains and defects in wood and wood products, and corrosion of other materials resulting from contact with wood. A member of the staff appeared as an expert witness in an arbitration case in which chemical factors were involved.

Timber Industry

Many inquiries concerning the technical properties of timbers have been received during the year; it is interesting to note that an appreciable number have emanated from timber merchants and users of timber in Continental countries. Apart from general utilization questions, advice and information has been sought on such matters as charcoal production, producer-gas plants for stationary and automobile engines, the effects of pruning on the quality of timber, plywoods and other forms of composite wood and adhesives for use in their manufacture.

Representation on Outside Committees

The Laboratory is represented on the following Committees:—

Standing Committee on Empire Forestry—

(Representative : Mr. W. A. Robertson).

Empire Forestry Association—

Governing Council

(Representative : Mr. W. A. Robertson).

Trade Names Committee

(Representatives : Mr. W. A. Robertson and Mr. B. J. Rendle).

Publications Committee

(*Representatives* : Mr. W. A. Robertson and Mr. H. A. Cox).

Agricultural Research Council—

Committee on Fungicides and Insecticides

(*Representative* : Mr. W. P. K. Findlay).

British Standards Institution—

Technical Committee AC/3, Plywood

(*Representative* : Mr. C. J. Chaplin).

Technical Committee B/10, Standard Definitions and Tests for Fire Resistance and Incombustibility

(*Representative* : Mr. N. A. Richardson).

Technical Committee B/14, Joinery

(*Representative* : Mr. C. J. Chaplin)

Technical Committee B/24 on Timber

(*Representative* : Mr. C. J. Chaplin).

Sub-Committee B/24/1 on Grading

(*Representative* : Mr. C. J. Chaplin).

Sub-Committee B/24/2, Methods of Testing Small Clear Specimens of Timber

(*Representative* : Mr. C. J. Chaplin)

Sub-Committee B/24/3 on Hardwood Grading

(*Representative* : Mr. C. J. Chaplin).

Sub-Committee B/24/4, Roadside Fencing

(*Representative* : Mr. C. J. Chaplin).

Sub-Committee B/24/5, Use of Timber in Building Construction

(*Representative* : Mr. C. J. Chaplin).

Sub-Committee C/10/2, Fungal Restraint by Antiseptic Substances

(*Representative* : Mr. K. St. G. Cartwright).

Panel C/10/2.1, Tests of Toxicity of Wood Preservatives

(*Representative* : Mr. K. St. G. Cartwright).

Technical Committee C/15 on Glues

(*Representative* : Miss C. B. Pettifor).

Technical Committee ME/37, Co-ordination of Mechanical Tests

(*Representative* : Miss C. B. Pettifor).

Sub-Committee ME/37/6, Tests of Non-Metallic Materials

(*Representative* : Miss C. B. Pettifor).

British Wood Preserving Association—

(*Member of Council* : Mr. W. A. Robertson).

National Home Grown Timber Council—

(*Member of Council* : Mr. W. A. Robertson).

Timber Development Association—

(Member of Council : Mr. H. A. Cox).

Public Relations Committee

(Representative : Mr. H. A. Cox).

Forestry Commission—

Advisory Committee on Forestry Research

(Representative : Mr. W. A. Robertson).

Home-grown Timbers Committee

(Representative : Mr. W. A. Robertson).

City of London College—

Timber Trades Advisory Committee

(Representative : Mr. W. A. Robertson).

City and Guilds of London Institute—

Advisory Committee on Woodcutting Machinists' Work

(Representative : Mr. P. Harris).

IV. WORK FOR THE EMPIRE OVERSEAS

Particulars of the work which was in progress on timbers from various parts of the overseas Empire during the period from 1st January to 29th April will be found in Appendix II. Since the latter date the following investigations have been completed and reports issued :—

Preliminary Investigations

1. White olivier : *Terminalia obovata* var. (Trinidad).
2. Nargusta : *Terminalia obovata* var. (Honduras).
3. Cramantee : *Guarea excelsa*, from British Honduras.
4. Waika chewstick : *Symphonia globulifera*, from British Honduras.
5. Cypress : *Podocarpus guatemalensis*, from British Honduras.
6. Idigbo : *Terminalia ivorensis*, from Nigeria.

All these timbers were found to possess qualities which rendered them suitable for general utility purposes. None, however, showed outstanding merit in any particular direction. Hence, while they will undoubtedly prove useful in the countries of origin, they will not in general command a sufficiently high price in the United Kingdom markets to cover costs of exploitation, transport, dock dues, and other incidentals. This does not apply to figured logs which prove suitable for conversion into veneers.

Special Investigations

The special investigation of certain of the properties of :—

1. Mukusu : *Entandrophragma angolense* and
2. Mufumbi : *Entandrophragma utile*, both from Uganda,

was completed and the report issued in August. The species are closely allied to the Sapele of West Africa, but the timber from the logs received did not generally show such attractive figure as Sapele and for that reason was less likely to command a satisfactory price in the markets of this country.

Very little work on Empire timbers is now in progress and that which is outstanding is approaching completion. The unfinished work includes:—

Special Investigations of the working qualities of

1. Queensland walnut : *Endiandra palmerstonii* and of
2. Meranti rambai daun : *Shorea acuminata*
3. Meranti temak : *Shorea hypochra*
4. Damar laut merah : *Shorea kunstleri*
5. Gerutu gerutu : *Parashorea lucida* and
6. Mengkulang : *Tarrietia simplicifolia*, from Malaya.

Service Tests of guarea (*Guarea thompsonii*) and scented guarea (*Guarea cedrata*), from Nigeria, have been made and confirm the supposition, based on laboratory tests of their technical properties, that they are worthy of consideration for the export trade.

APPENDIX I

STAFF OF THE FOREST PRODUCTS RESEARCH LABORATORY

Director of Forest Products Research : W. A. Robertson.

Principal Scientific Officer : S. T. C. Stillwell, B.Sc.

Temporary Assistant : A. N. David, Dip. For.

Clerk (Higher Grade) : L. Forbes.

Assistant II : W. R. Hutchins.

SECTION OF TIMBER INDUSTRY

Scientific Officers : H. A. Cox, M.A., Dip.For., Dip.Tim.Tech.; P. Harris, B.Sc.;

R. A. G. Knight, B.Sc.(Eng.), A.M.I.Mech.E.

Assistant II : G. H. Donald, B.A.

Assistant III : H. J. Endersby.

SECTION OF WOOD STRUCTURE

Scientific Officers : B. J. Rendle, B.Sc., A.R.C.S.; S. H. Clarke, M.Sc.;

E. W. J. Phillips, B.Sc., A.R.C.S.

Assistant III : C. L. Stocker, B.A., Dip.For.

SECTION OF TIMBER PHYSICS

Senior Scientific Officer : W. W. Barkas, M.Sc.

Scientific Officer : E. D. van Rest, B.A., B.Sc., F.S.S.

Junior Scientific Officer : A. R. Bryant, B.Sc.

Assistant III : R. F. S. Hearmon.

SECTION OF SEASONING.

Scientific Officers : R. G. Bateson, B.A.; W. C. Stevens, M.A., A.M.I.Mech.E.

Assistants III : A. R. Dean; R. E. Hodge; D. D. Johnston; R. J. Newall;

G. H. Pratt; N. Turner.

SECTION OF TIMBER MECHANICS

Timber Mechanics Officer : C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E.

Scientific Officers : F. H. Armstrong, M.Sc., A.M.I.Mech.E.; J. Latham, B.Sc.;

E. H. Nevard, B.Sc.(Eng.), D. K. C.; Miss C. B. Pettifor, B.Sc.

Assistant II : A. J. Foord.

Assistant III : F. L. Arney.

SECTION OF WOOD PRESERVATION

Scientific Officers : J. Bryan, M.Eng., A.M.Inst.C.E.; N. A. Richardson, B.Sc., A.I.C.

Assistants III : L. S. Doman, E. E. Larner, D. N. Smith, S. J. W. Smith.

SECTION OF ENTOMOLOGY

Senior Scientific Officer : R. C. Fisher, B.Sc., Ph.D.

Scientific Officers : F. R. Cann, D.I.C.; E. A. Parkin, M.Sc., Ph.D., D.I.C.

Assistant III : E. C. Harris.

SECTION OF MYCOLOGY

Senior Scientific Officer : K. St. G. Cartwright, M.A., D.I.C., F.L.S.

Scientific Officer : W. P. K. Findlay, M.Sc., A.R.C.S., D.I.C.

Assistants III : E. C. Badcock; Miss E. C. M. Ernest, B.Sc., Ph.D., D.I.C.

SECTION OF WOOD CHEMISTRY

Senior Scientific Officer : W. G. Campbell, B.Sc., M.S., A.I.C.

Scientific Officers : S. A. Bryant, B.A., A.I.C.; Miss M. H. O'Dwyer, B.Sc.,
Ph.D., D.I.C.

Junior Scientific Officer : J. C. McGowan, B.A., B.Sc., D.I.C., A.I.C.

Assistant III : D. F. Packman.

SECTION OF PUBLICATIONS AND RECORDS

Assistant I : C. J. N. McCracken, B.A., Dip.For.

Assistant III : Miss M. B. Hyde, M.Sc.

On 31st December, 1938, the Staff of the Laboratory numbered 141.

APPENDIX II

STANDING CONFERENCE ON TIMBER UTILIZATION
REPORT⁽¹⁾ OF THE STANDING CONFERENCE FOR THE PERIOD
1ST JANUARY TO 29TH APRIL, 1938

There was no change in the constitution of the Conference during the period under review.

MEETINGS AND BUSINESS DONE

There was one meeting only in 1938—on 29th April—held at 16, Old Queen Street, Westminster. The Chairman presided, and in addition eight representatives of the various units of Empire appointing to membership were present. The Conference received a report from the Department and discussed the desirability of circulating the text of the new Handbook of Empire Timbers to representatives prior to publication. It was decided that such a course would inevitably result in considerable delay, and therefore was not desirable. The Report of the Conference for the year 1937 was considered and approved. Two papers entitled "Variations in Strength of Pine Timbers" and "Property Classification of Raw Materials of Wood-Using Industries" respectively were submitted for consideration by the High Commissioner for the Union of South Africa. The desirability of keeping the Conference in existence was then discussed, and it was agreed that the purposes for which the Conference had been brought into being had been fulfilled, and therefore it was decided to recommend to the units of Empire appointing to membership that it should be brought to an end.

The Chairman and Members of the Conference desire to record that their work has been greatly facilitated by the courtesy of the Director of Forest Products Research and by the efficiency of Mr. H. A. Cox, who has acted as Secretary.

(Sgd.) JOHN STIRLING MAXWELL,
Chairman.

15th July, 1938.

REPORT BY THE DEPARTMENT TO THE CONFERENCE ON
THE INVESTIGATION OF EMPIRE TIMBERS FOR THE PERIOD
1ST JANUARY TO 29TH APRIL, 1938

No new tests of Empire timbers have been started since the beginning of 1938. A consignment of white afara, *Terminalia superba*, from Nigeria, arrived at the Laboratory at the end of January, but on examination was found to be unfit for test, every log showing extensive decay in the heart.

APPLICATIONS FOR TESTS

No new application for tests of Empire timbers was received during the period.

PROGRESS OF INVESTIGATIONS

A. Investigations completed

Preliminary Investigations

1. Timbersweet : *Nectandra* sp. or *Ocotea* sp. (exact identity undetermined), from British Honduras.

⁽¹⁾ Being a report prepared by the Conference under Standing Order No. 9, which provides for the submission annually to the co-operating bodies of an Annual Report of the proceedings of the Conference (see Appendix II B).

The investigation of the properties of timbersweet was actually finished at the end of 1937, but too late for the report to be issued in that year. The wood was found to possess good strength properties and to season without much difficulty. It should prove a very useful timber for use in the country of origin, and might find a market in the West Indies, but it is not sufficiently valuable to command an economic price in the United Kingdom.

2. *Guarea* : *Guarea thompsonii*
Scented guarea : *Guarea cedrata* } from Nigeria.

The tests on these two species of *Guarea* have been completed and a report has been issued. The results of the investigation indicate that both species are promising, possessing properties which entitle them to be considered for the export markets.

Special Investigations

3. African pencil cedar : *Juniperus procera*, from Kenya and Tanganyika Territory.

The special investigation, undertaken with the object of finding a method of softening the wood to improve its cutability and to determine the cause of warping with a view to its prevention, has been completed. It is proposed to publish the results of this work in Forest Products Research Record No. 24.

4. Mvule : *Chlorophora excelsa*, from Uganda.

The investigation of certain of the properties of mvule has been finished, and the report has been issued. The wood appears to be comparable in every way to iroko from West Africa.

- B. Investigations in Progress on 1st January, but not completed on 29th April, 1938

Preliminary Investigations

5. White olivier : *Terminalia obovata* var. (Trinidad).
6. Nargusta : *Terminalia obovata* var. (Honduras).
7. Cramantee : *Guarea excelsa*, from British Honduras.
8. Waika chewstick : *Symphonia globulifera*, from British Honduras.
9. Cypress : *Podocarpus gautemalensis*, from British Honduras.

The preliminary investigations on the five species named above are all practically finished, and it is hoped to be able to issue the reports at an early date.

10. Black afara : *Terminalia ivorensis*, from Nigeria.

All tests except those on air-seasoned material have been completed. As the air-seasoning is not yet finished further work is delayed until the moisture content in the remaining stock has been reduced to the necessary percentage.

Special Investigations

11. Queensland walnut : *Endiandra palmerstonii*.

Some further tests to determine the dulling effect on tools in comparison with other timbers remain to be done.

12. Meranti rambai daun : *Shorea acuminata*
Meranti temak : *Shorea hypochra*
Damar laut merah : *Shorea kunstleri*
Gerutu gerutu : *Parashorea lucida*
Mengkulang : *Tarrietia simplicifolia* } all from Malaya.

The tests of the working qualities of the above five species from Malaya have not yet been started.

13. Mukusu : *Entandrophragma angolense*
Mufumbi : *Entandrophragma utile* } from Uganda.

The special investigations of certain of the properties of the two species of *Entandrophragma* are now almost finished, and it is expected that the reports will be ready for issue at an early date.

APPENDIX IIA.

STANDING CONFERENCE ON TIMBER UTILIZATION
CONSTITUTION*Chairman :*

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APPENDIX IIB

*(Revised 10th September, 1935)*RULES AND STANDING ORDERS OF THE STANDING
CONFERENCE ON TIMBER UTILIZATION1. *Objects*

The Department of Scientific and Industrial Research having agreed to hold available, for the assistance of the various parts of the Empire overseas, under financial arrangements to be approved from time to time by the Department, the facilities of its Forest Products Research Laboratory at Princes Risborough for the investigation of the qualities of particular timbers (which determine their uses) and for furnishing technical information of importance in marketing such timbers, it has been decided to establish a standing conference to act as a consultative and advisory body to the Department and to the various units of the Empire overseas which desire to make use of these facilities, or to be represented on the Conference.

2. *Constitution*

Any dominion, colony, or other unit of the Empire overseas which makes use of these facilities or expresses a wish to be represented on the Conference will be entitled to appoint one or more representatives to membership of the Conference. The names of all representatives so appointed will be communicated to the Department by the Office of the appointing unit of Empire. The Department will appoint representatives to be members of the Conference who may include persons nominated by other Departments of State in the United Kingdom interested in the use of Empire-grown timbers, a person or persons nominated by the Minister of Agriculture and Fisheries as representing the Royal Botanic Gardens at Kew, persons nominated by the Governing Bodies of the Imperial Institute and the Imperial Forestry Institute, persons nominated by any timber trade organisation in the United Kingdom on an invitation issued on the recommendation of the Standing Conference, and persons not included in the foregoing categories who have in the past been of conspicuous service, as members of the Empire Timbers Committee or otherwise in promoting the use of Empire-grown timbers in the United Kingdom.

3. *The Year*

For the purpose of these rules and standing orders the year is understood to run from January 1st to December 31st.

4. *Chairman*

The Chairman will be appointed by the Department from among the members of the Conference as defined by its constitution as set out in 2 above. He will hold office for three years, and will be eligible for reappointment for a further period, not exceeding three years, on the completion of a term of office.

5. *Secretarial work and place of meeting*

The Department will undertake the secretarial work of the Conference and will provide a place for its meetings.

6. *Meetings*

Two ordinary meetings of the Conference will be held in each year. A notice of the date, time and place of each ordinary meeting will be sent to each member one month before the meeting. A special meeting may be called at any time by the Chairman in his discretion and shall be called by the Chairman on the requisition of the representative, or, if more than one, the representatives of any unit of the Empire appointing to membership of Conference, such requisition to be accompanied by notice of the question or questions to be raised at the meeting. At least one week's notice of the date, time and place of each special meeting will be sent to each member.

7. *Business*

The regulation of the business of the meetings of the Conference will be in the hands of the Chairman. A member wishing to bring any matter before a meeting of the Conference is requested to give notice to the Director, Forest Products Research Laboratory, Princes Risborough, Bucks, fourteen days before the meeting, so that the matter may be included as an item on the agenda. Matters to be so brought before the Conference would include those which bear on the marketing of any timber grown in the part of the Empire overseas which the member may represent. An agenda paper for each meeting will be circulated so as to reach members at least three days before the meeting.

8. *Presentation of reports to the Conference*

A brief progress report on the work carried out by the Department on Empire-grown timbers under the arrangements defined in 1 above during the period since the last ordinary meeting of the Conference will be presented to

the Conference at each ordinary meeting by the Department. Members representing various units of the Empire overseas or the institutions or trade organisations defined in 2 above are invited to present similarly to the Conference progress reports on any work carried out by the unit of Empire, institution or organisation they represent which appears to be of general interest in promoting the objects of the Conference. Such reports should reach the Director, Forest Products Research Laboratory, at least fourteen days before the meeting at which they are to be presented.

9. Reports of the proceedings of the Conference

As soon as possible after December 31st in each year, the Conference will present to the bodies appointing members a report of its proceedings during the past year. These reports may be printed and published by the Department in its discretion.

APPENDIX III—PUBLICATIONS

(A complete list to date of the Laboratory's publications may be obtained on application to the Director, Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.)

I.—LIST OF PUBLICATIONS ISSUED DURING 1938

A.—STATIONERY OFFICE PUBLICATIONS*

	Price s. d.
Report of the Forest Products Research Board for the Year 1937 ..	2 0

BULLETINS :—

No. 1.—Dry Rot in Wood. By K. St. G. Cartwright, M.A., F.L.S., and W. P. K. Findlay, M.Sc., D.I.C. (3rd Edition)	1 0
No. 18.—Commercial Mahoganies and allied Timbers. By B. J. Rendle, B.Sc., A.R.C.S.	2 0

RECORDS :—

No. 4.—Timber Seasoning. By R. G. Bateson, B.A. (2nd Edition)	0 6
No. 23.—Kiln-seasoning Treatments of Teak and their Effects on its Wearing Qualities as Flooring. By R. A. G. Knight, B.Sc.(Eng.), A.M.I.Mech.E.; A. R. Dean; and F. H. Armstrong, M.Sc., A.M.I.Mech.E.	0 6
No. 24.—African Pencil Cedar. Studies of the Properties of <i>Juniperus procera</i> (Hochst.), with particular Reference to the Adaptation of the Timber to the Requirements of the Pencil Trade	0 6
No. 25.—Machinery and Equipment used for Bending Wood. By W. C. Stevens, M.A., A.M.I.Mech.E.	0 6
No. 26.—Kiln-drying Schedules. By R. G. Bateson, B.A.; and R. E. Hodge	0 6
No. 27.—Decay of Timber and its Prevention. By W. P. K. Findlay, M.Sc., D.I.C.	0 6

SPECIAL REPORTS :—

No. 4.—Recent Work on the Moisture in Wood in Relation to Strength and Shrinkage. By W. W. Barkas, M.Sc. ..	0 9
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LEAFLETS† :—

No. 3.— <i>Lyctus</i> Powder-post Beetles. (Revised Edition)	
No. 6.—Dry Rot in Buildings. Recognition, Prevention and Cure. (Revised Edition)	
No. 8.—The Common Furniture Beetle. (Revised Edition)	
No. 9.—The Moisture Content of Timber in Use. (Revised Edition)	
No. 10.—Timber Drying Kilns. The Overhead Internal Fan Kiln. (Simplified Design.) (Revised Edition)	
No. 11.—The Hot and Cold Open Tank Process of Impregnating Timber. (Revised Edition)	
No. 12.—Sap-stain in Timber. Its Cause, Recognition and Prevention. (Revised Edition)	
No. 14.—The House Longhorn Beetle	

* Obtainable from any of the Sale Offices of His Majesty's Stationery Office.

LONDON: York House, Kingsway, W.C.2; EDINBURGH: 120, George Street; MANCHESTER: 26, York Street; CARDIFF: 1, St. Andrew's Crescent; BELFAST: 80, Chichester Street.

† The Leaflets are obtainable gratis from the Director, Forest Products Research Laboratory.

MISCELLANEOUS :—

- Principal Decays of Softwoods used in Great Britain. By K. St. G. Cartwright, M.Sc., F.L.S., and W. P. K. Findlay, M.Sc., D.I.C. . . 2 6

B.—Other Publications*

- BARKAS, W. W., and GOLDER, H. Q.
Relation of Strength of Wood to Shrinkage. *Nature*, 1938, **141**, 874.
- BARR, G., THOROGOOD, A. L., and VAN REST, E. D.
The Diffusion and Effusion of some Gases through Wood. *J. Soc. chem. Ind., Lond.*, 1938, **57**, 339-344.
- BATESON, R. G.
Nomogram Method of Humidity Control. *Engineering*, 1938, **146**, 57.
Sorbitol in Wood Treatment. Further Experiments on Shrinkage and Swelling Behaviour. *Chem. Tr. J.*, 1938, **103**, No. 2668, 26-27.
Seasoning Timber to Suit the Purposes for which it is to be used. *Timb. News Sawm. Chron.*, 1938, **46**, 387-388.
Humidity in the British Isles. *Nature*, 1938, **142**, 1123.
- BRYAN, J.
The Fire-Proofing of Timber. *Fire Protection*, 1938, **1**, 16-17.
- CAMPBELL, W. G., HIRST, E. L., and YOUNG, G. T.
Estimation of Uronic Anhydride Residues in Polysaccharides. *Nature*, 1938, **142**, 912-913.
- CAMPBELL, W. G., MCGOWAN, J. C., and BRYANT, S. A.
The Chlorine-Sodium Sulphite Colour Reaction of Woody Tissues. II. The Bearing of the Colour Reaction on the Constitution of Hardwood Lignin. *Biochem. J.*, 1938, **32**, 2138-2141.
- CAMPBELL, W. G., and SWANN, G.
The Bleaching Action of Alkaline Hydrogen Peroxide on Wood. *Biochem. J.*, 1938, **32**, 702-707.
- CANN, F. R.
An Uncommon Type of Furniture Beetle Damage in Softwoods. *Builder, Lond.*, 1938, **154**, 654-655.
- CARTWRIGHT, K. ST. G.
A Further Note on Fungus Association in the Siricidae. *Ann. appl. Biol.*, 1938, **25**, 430-432.
- CHAPLIN, C. J.
The Container Testing Laboratory. *J. R. Soc. Arts*, 1938, **87**, 78-84.
- CLARKE, S. H.
A Multiple-entry Perforated-card Key with special Reference to the Identification of Hardwoods. *New Phytol.*, 1938, **37**, 369-374.
Fine Structure of the Plant Cell Wall. *Nature*, 1938, **142**, 899-904.
The Properties of Timbers as influenced by Growth in Tropical Climates. *Emp. For. J.*, 1938, **17**, 247-248.
- DONALD, G. H.
Wood and Charcoal as Motor Fuels. *Emp. For. J.*, 1938, **17**, 70-74.
- FINDLAY, W. P. K.
The Natural Resistance to Decay of some Empire Timbers. *Emp. For. J.*, 1938, **17**, 249-259.

* Reprints of some of the Papers are obtainable at a nominal cost from the Director, Forest Products Research Laboratory.

FISHER, R. C.

Studies in the Biology of the Death Watch Beetle (*Xestobium rufovillosum* De G.). II. The Habits of the Adult, with special Reference to Factors affecting Oviposition. *Ann. appl. Biol.* 1938, **25**, 155-180.

Insurance of Buildings against Insect or Dry Rot Attack. *Post Mag. Insur. Monit.*, 1938, **99**, 845, 847.

HARRIS, P.

Causes and Remedies for Chip-bruising in Planing. *Timb. News Sawm. Chron.*, 1938, **46**, 307.

Automatic Operation of Cine-camera and Lighting Arrangements for Time Lapse Studies. *Nature*, 1938, **142**, 834.

Woodcutting Research. How Experiments on Tools are carried out at the Forest Products Research Laboratory. *Timb. Tr. J.*, 1938, **147**, No. 3242, 242, xx.

Sawmilling Methods. Machines for Sawing Logs and Timber—Advantages and Limitations of the Various Types considered. *Timb. Tr. J.*, 1938, **147**, No. 3249, 738, 789.

KNIGHT, R. A. G.

A Moisture-Content Controller for Timber Stores. *Wood*, 1938, **3**, 595.

KNIGHT, R. A. G., and NEWALL, R. T.

Permanent Set of Timber. *Forestry*, 1938, **12**, 125-135.

LATHAM, J.

The Improved Tumbling Drum Test. *J. R. Soc. Arts.*, 1938, **87**, 84-87.

PARKIN, E. A.

The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. II. A Preliminary Experiment upon the Effect of Girdling Standing Oak Trees. *Forestry*, 1938, **12**, 30-37.

The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. III. A Second Experiment upon the Girdling of Standing Oak Trees. *Forestry*, 1938, **12**, 117-124.

PETTIFOR, C. B.

Statistical Methods used in Determination of Specification Limits for Egg Containers. *J. R. Soc. Arts*, 1938, **87**, 88-93.

PHILLIPS, E. W. J.

The Depletion of Starch from Timber in Relation to Attack by *Lyctus* Beetles. I. Starch, with special Reference to its Occurrence in Timber. *Forestry*, 1938, **12**, 15-29.

RICHARDSON, N. A.

Coal Tar Creosote and Wood Preservation. *West's Gas*, 1938 (Summer Number), 36-41.

ROBERTSON, W. A.

The Utilization of Home-grown Hardwoods. (Paper read before the Forestry Section of the British Association, 1938).

Timber Testing in Relation to Building Regulations in Great Britain. (Paper read at the Fourth International Conference on Timber Utilisation, Brussels, 1938).

STEVENS, W. C.

The Shrinkage and Expansion of Wood. *Forestry*, 1938, **12**, 38-43.

Containers for National Mark Eggs. *Paper Cont.*, 1938, **38**, 105-107; 145-146; 185, 187-188.

II.—LIST OF PUBLICATIONS ISSUED THROUGH H.M. STATIONERY OFFICE PRIOR TO 1938

	Price s. d.
Report of the Forest Products Research Board for the Period ended 30th September, 1928	3 0
Report of the Forest Products Research Board for the Period ended 31st December, 1929	4 0
Report of the Forest Products Research Board for the Year 1930 ..	4 0
Report of the Forest Products Research Board for the Year 1931 ..	3 6
Report of the Forest Products Research Board for the Year 1932 ..	4 0
Report of the Forest Products Research Board for the Year 1933 ..	1 3
Report of the Forest Products Research Board for the Year 1934 ..	1 6
Report of the Forest Products Research Board for the Year 1935 ..	2 0
Report of the Forest Products Research Board for the Year 1936 ..	1 6
Report of the Forest Products Research Board for the Year 1937 ..	2 0

TECHNICAL PAPERS :—

- No. 1.—The Movement of Moisture with Reference to Timber
Seasoning. By S. T. C. Stillwell, B.Sc. (Out of print)
- No. 2.—Moisture Movement through Wood. The Steady State.
By J. F. Martley, D.I.C., B.Sc. (Out of print)

SPECIAL REPORTS :—

- No. 1.—The Air-Seasoning and Conditioning of Timber. By
F. M. Oliphant (Out of print)
- No. 2.—The Principles of Kiln-Seasoning of Timber. Part I.
Types of Commercial Kilns in Use. By S. T. C.
Stillwell, B.Sc. (1928) 0 9
- No. 3.—Practical Kiln-Drying. By W. C. Stevens, M.A.,
A.M.I.Mech.E. (Out of print. Superseded by Records
Nos. 4, 13 and 26.)

BULLETINS :—

- No. 2.—*Lyctus* Powder-post Beetles. By R. C. Fisher, B.Sc.,
Ph.D. (Out of print)
- No. 3.—British Hardwoods. Their Structure and Identification.
By L. Chalk, M.A. and B. J. Rendle, B.Sc. .. (1929) 5 0
- No. 4.—Decay of Sitka Spruce caused by *Trametes serialis* Fr.
By K. St. G. Cartwright, B.A. (1930) 2 0
- No. 5.—The Moisture Content of Wood with Reference to
Furniture Manufacture. By S. T. C. Stillwell, B.Sc.
(1930) 2 0
- No. 6.—The Timber of Corsican Pine (*Pinus laricio* Poiret) (1930) 2 6
- No. 7.—Home-grown Timbers. Their Anatomical Structure and
its Relation to Physical Properties. Elm. By S. H.
Clarke, B.Sc. (1930) 3 6
- No. 8.—The Use of Home-grown Larch for Transmission Lines
(1931) 2 0
- No. 9.—Home-grown Pitprops (1931) 2 0
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- No. 11.—The Effect of Progressive Decay by *Trametes serialis* Fr.
on the Mechanical Strength of the Wood of Sitka
Spruce. By K. St. G. Cartwright, M.A.; W. P. K.
Findlay, M.Sc.; C. J. Chaplin, M.Sc.; and W. G.
Campbell, B.Sc., M.S. (1931) 1 6
- No. 12.—Some Characteristics of Home-grown Timbers. By C. J.
Chaplin, M.Sc., M.E.I.C.; J. Latham, B.Sc.; and F. H.
Armstrong, M.Sc., A.M.I.Mech.E. (1931) 2 0

- No. 13.—The Principles of Woodworking. A Survey of Present Knowledge of this Subject. By W. W. Barkas, M.Sc.; E. D. van Rest, B.A., B.Sc.; and W. E. Wilson (*Out of print*)
- No. 15.—The Timber of Home-grown Scots Pine (*Pinus sylvestris* L.) (1932) 5 0
- No. 16.—A Survey of the Damage caused by Insects to Hardwood Timbers in Great Britain. By R. C. Fisher, B.Sc., Ph.D.; F. R. Cann, D.I.C.; and E. A. Parkin, B.Sc., D.I.C. (1932) 2 6
- No. 17.—Methods of bending Wood by Hand. By W. C. Stevens, M.A., A.M.I.Mech.E.; and N. Turner.. .. (1937) 1 0

*LEAFLETS :—

- No. 1.—Worm in Furniture. (*Out of print. Superseded by Leaflets Nos. 3, 4 and 8.*)
- No. 2.—The Influence of Certain Factors on the Kiln-drying of Timber and on the Choice of the Types of Drying Kiln By S. T. C. Stillwell, B.Sc. (*Out of print. Superseded by Record No. 13.*)
- No. 4.—The Death Watch Beetle. (*Revised Edition*) .. (1936)
- No. 5.—Empire Timbers from Home and Overseas for Building and Structural Purposes. By Major J. R. Cosgrove, D.S.O., M.C., M.E.I.C. (1932) 1 3
- No. 7.—Moisture Content Determination by the Oven-drying Method. (*Revised Edition*) (1937)
- No. 13.—The Kiln Sterilisation of *Lyctus*-infested Timber (1937)

MISCELLANEOUS :—

- The Uses of Home-grown Timber (*Out of print*)
- The Principal Rots of English Oak. By K. St. G. Cartwright, M.A., F.L.S.; and W. P. K. Findlay, M.Sc., D.I.C. 2 0
- A Handbook of Home-grown Timbers (1936) 1 6

PROJECTS :—

- Project 1.—Mechanical and Physical Properties of Timber. Tests of Small Clear Specimens. By C. J. Chaplin, M.Sc., M.E.I.C. (1928) 2 0
- Project 1.—Progress Report 1. Tests on some Home-grown Timbers in their Green Condition. By C. J. Chaplin, M.Sc., M.E.I.C. (1928) 0 9
- Project 1.—Progress Report 2. Tests of some Home-grown Timbers in their Green and Seasoned Conditions. By C. J. Chaplin, M.Sc., M.E.I.C.; and F. M. Mooney, B.Sc., A.M.E.I.C. (1929) 1 0

RECORDS :—

- No. 1.—The Testing of Timbers at the Forest Products Research Laboratory (1935) 0 6
- No. 2.—Strength Tests of Structural Timbers. Part 1. General Principles, with Data on Redwood from Gefle and Archangel. By C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E.; and J. Latham, B.Sc. (1935) 0 6
- No. 3.—Experiments on the Preservation of Mine Timber. Progress Report No. 1. By J. Bryan, M.Eng., A.M.I.C.E.; and N. A. Richardson, B.Sc., A.I.C. (1935) 0 6
- No. 5.—The Moisture Content of Timber in New Buildings. By R. A. G. Knight, B.Sc. (Eng.), A.M.I.Mech.E. (1935) 0 6

* The Leaflets (with the exception of No. 5) are obtainable gratis from the Director, Forest Products Research Laboratory.

	Price s. d.
No. 6.—The Properties of an African Mahogany (<i>Khaya anthotheca</i> C.DC.) (1936)	0 6
No. 7.—The Properties of Mansonia (<i>Mansonia altissima</i> A. Chev.) (1936)	0 6
No. 8.—Strength Tests of Structural Timbers. Part 2. General Procedure of Selecting and Testing Joists, with Data on British Columbian Douglas Fir, <i>Pseudotsuga douglasii</i> Carr. By C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E.; and E. H. Nevard, B.Sc. .. . (1936)	0 6
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No. 10.—The Practice of Wood Bending. By W. C. Stevens, M.A., A.M.I.Mech.E. (1936)	0 6
No. 11.—The Properties of Home-Grown Oak (1936)	0 6
No. 12.—Seraya, Meranti and Lauan. By B. J. Rendle, B.Sc., A.R.C.S.; and S. H. Clarke, M.Sc. (1936)	0 6
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No. 15.—Strength Tests of Structural Timbers. Part 3. Development of Safe Loads and Stresses, with Data on Baltic Redwood and Eastern Canadian Spruce. By C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E.; and E. H. Nevard, B.Sc. (1937)	0 6
No. 16.—Gurjun, Apitong, Keruing, Kapur and allied Timbers. By S. H. Clarke, M.Sc. (1937)	0 6
No. 17.—Wood Preservatives. By N. A. Richardson, B.Sc., A.I.C. (1937)	0 6
No. 18.—The Causes of Stain and Decay in Imported Timber. By K. St. G. Cartwright, M.A. (Oxon), D.I.C., F.L.S. (1937)	0 6
No. 19.—Methods of Kiln Operation. By R. G. Bateson, B.A. (1937)	0 6
No. 20.—The Properties of British Honduras Pitch Pine (Slash Pine)— <i>Pinus caribaea</i> Mor. (1937)	0 6
No. 21.—The Growth and Structure of Wood. By B. J. Rendle, B.Sc., A.R.C.S. (1937)	0 6
No. 22.—Circular Saws. By P. Harris, B.Sc. (Eng.) .. (1937)	0 6

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LONDON

PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased directly from H.M. STATIONERY OFFICE at the following addresses :

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